Pliocene and Pleistocene Pollen Stratigraphy in Central and Southwestern Japan

Onishi, Ikuo

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Pliocene and Pleistocene Pollen Stratigraphy in Central and Southwestern Japan

By

Ikuo ONISHI*

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Abstract

The floral change, like as the faunal succession, the paleomagnetic chronology and the absolute age, is one of the most important means for the subdivisions of the Pliocene and Pleistocene time. In Kinki district, the studies of the Plio-Pleistocene flora have been proceeded since the 1930's. And the floral subdivisions in this district have been proposed by several workers (Fig. 3).

The writer rearranges these plant fossils into 14 stratigraphic divisions (see Appendix). As the result, it is definitely shown that the following 7 macrofloras, in descending order, have the distinctive features.

7. Yokooji Flora (=*Aphananthe* flora)
6. Nishinomiya Flora (=*Larix gmerinii* and *Syzygium* floras)
5. Nishiyama Flora (=*Paliurus nipponicus* flora)
4. Ibaraki Flora (=*Metasequoia* flora)
3. Sennan Flora (=Transitional flora 2)
2. Shimagahara Flora (=Transitional flora 1)
1. Seto Flora (=*Pinus trifolia* flora)

Pollen analysis is carried out on the samples covering almost all horizons of the Pliocene and Pleistocene deposits in Kinki and Tokai districts. Based on the feature of each pollen spectrum, the following 14 pollen assemblages are distinguished (ONISHI, 1975). Judging from the contained taxa and the stratigraphic horizon, some pollen assemblages can be connected with the above-mentioned macrofloras as shown in parenthesis.

1) *Cyclobalanopsis-Carya* assemblage (Seto Flora)
2) *Cyclobalanopsis-Podocarpus* assemblage (*Syzygium* flora)
3) *Cyclobalanopsis-Abies* assemblage (Yokooji Flora)
4) *Quercus-Liquidambar* assemblage (Sennan Flora)
5) *Quercus*-Taxodiaceae assemblage
6) *Fagus-Quercus* assemblage
7) Taxodiaceae-*Zelkova* assemblage
8) *Metasequoia-Picea* A assemblage (Ibaraki Flora)
9) *Fagus-Nyssa* assemblage (Shimagahara Flora)
10) *Fagus-Cryptomeria* assemblage
11) *Fagus-Tsuga* assemblage
12) *Diploxylon-Cryptomeria* assemblage
13) *Picea-Cryptomeria* assemblage
14) *Picea-Haploxylon* assemblage

Based on the stratigraphic distribution of these pollen assemblages, 8 pollen zones, K 1 to K 8 in

* Department of Geology, Faculty of Science, Shimane University, Matsue, Shimane.

ascending order, are distinguished in these districts (ONISHI, 1975) and are used as the standard for correlation.

Pollen analysis is also carried out on the samples from the other 5 districts in central and southwest Japan. As the result, the following pollen assemblages are added.

15) *Ulmus-Zelkova* assemblage
16) *Haploxylon-Abies* assemblage
17) *Haploxylon-Cryptomeria* assemblage
18) Taxodiaceae-Pinaceae assemblage

The Pliocene and Pleistocene deposits of each district are divided into the following pollen zones. And each zone is correlated to the standard zone of Kinki and Tokai districts (Fig. 28).

A) OITA DISTRICT: In total, 7 pollen assemblages and 4 pollen zones, named O 1 to O 4, are distinguished in the Oita Group and Oka Formation.

B) SAN'IN DISTRICT: In the Plio-Pleistocene Tsunozu Group, 4 pollen assemblages and 3 pollen zones, called T 1 to T 3, are recognized. The middle and late Pleistocene deposits, in which 3 pollen assemblages are involved, compose zone S 1. The latest Pleistocene and Holocene deposits which involve 3 pollen assemblages compose zone S 2.

C) HOKURIKU DISTRICT: The Omma Formation involves *Picea-Haploxylon* assemblage and composes zone H 1 and the Utatsuyama Formation has *Fagus-Quercus* assemblage and composes zone H 2.

D) KANTO DISTRICT: In the Plio-Pleistocene Kazusa Group which have been divided into 6 pollen zones, here named B 1 to B 6, 6 pollen assemblages are distinguished.

E) NIIGATA DISTRICT: In the Pliocene Chuetsu Group and the Plio-Pleistocene Uonuma Group, 4 pollen assemblages are recognized. Several pollen zones have already been reported. Summarizing these data, 8 pollen zones, named N 1 to N 8, are distinguished.

Pollen zones obtained from 6 districts are summarized into the following 7 pollen zones in descending order.

Abies Zone, *Cryptomeria* Zone, *Fagus* Zone, *Metasequoia* Zone, Taxodiaceae Zone, *Liquidambar* Zone, and *Carya-Nyssa* Zone.

The Plio-Pleistocene boundary which have been proposed by ITIHARA in Kinki district approximately agrees with the base of the *Metasequoia* Zone.

The correlation by means of these pollen zones is compared with the correlations based on the other criteria, such as the proboscidean fauna, the paleomagnetism and the absolute age. As the result, these correlations well agree with each other.

The relations between pollen zones and the other criteria are as follows.

A) Proboscidean Fauna

The range of *Elephas naumanni* is restricted in the upper half of the *Cryptomeria* Zone and that of *Stegodon orientalis* is in the lower half of this zone. *Stegodon* cf. *elephantoides* occurs within the *Liquidambar* Zone. The coexistence of *Elephas shigensis* and *Stegodon akashiensis* is restricted approximately in the *Metasequoia* Zone.

B) Paleomagnetism

The lower boundaries of Brunhes, Matuyama and Gauss Epochs are respectively situated in the upper parts of *Fagus, Liquidambar* and *Carya-Nyssa* Zones.

C) Absolute Age

The boundary between *Abies* and *Cryptomeria* Zones is estimated to be about 25,000 years B. P. based on ^{14}C ages. The lower boundaries of *Cryptomeria, Fagus* and *Metasequoia* Zones are respectively estimated to be about 0.5, 1.0 and 2.0 million years based on fission-track ages.

I. Introduction

The floral succession, like as the faunal succession, the paleomagnetic chronology

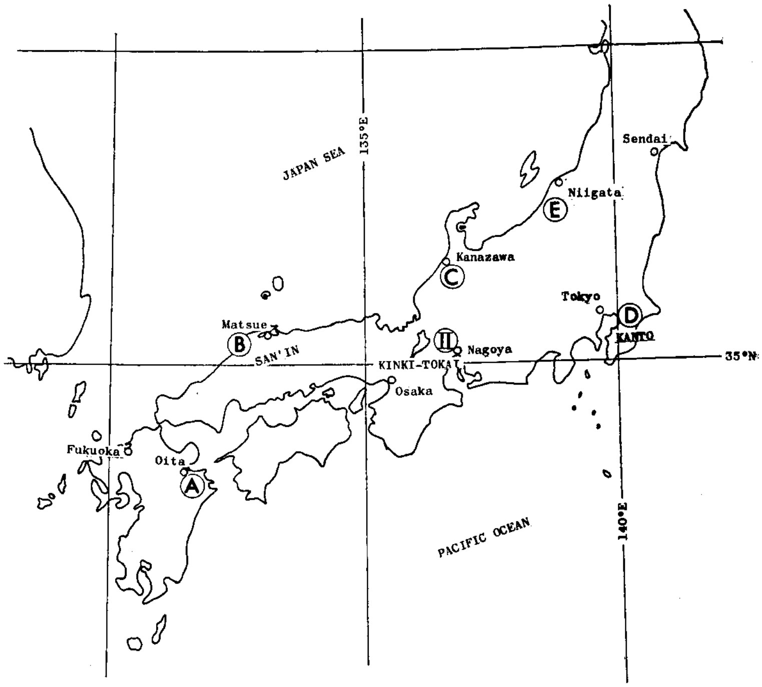

Fig. 1. Index map of sampling districts.
II; Kinki and Tokai districts. A; Oita district. B; San'in district.
C; Hokuriku district. D; Kanto district. E; Niigata district.

and the absolute age, is one of the most important means for the subdivision of the Pliocene and Pleistocene time. In Kinki and Tokai districts, the studies of the Plio-Pleistocene flora have been proceeded since 1933, when MIKI presented the detailed floral list in the Province of Yamashiro (Kyoto Prefecture). Since then, the floral subdivisions in these districts have been proposed by several workers. In addition to the macrofloras, pollen analytical studies were initiated by SHIMAKURA (1956) and succeeded by several workers in these districts.

As the macro- and micro-floras have also been investigated in the other districts, the floral standard for correlation may be applicable for all over Japan.

Some other standards for the Pliocene and Pleistocene correlation have been clarified in several parts of Japan. Therefore, the detailed correlations based on the plural methods can be given.

The writer has studied the pollen floras of the Plio-Pleistocene strata in central and southwestern Japan. In this paper, he wishes to present the pollen evidences and to make the pollen stratigraphic correlation. Besids, he aims to examine whether this correlation agrees with those from the other standards.

II. Pollen analysis in Kinki and Tokai Districts

A. Stratigraphic notes

The Pliocene and Pleistocene Series in Kinki and Tokai districts are composed of two units (ITIHARA, 1960). The older one is called the second Setouchi Supergroup that deposited in the second Setouchi inland sea (IKEBE, 1956), suffered the tectonic movement and left the dissected hilly surface called the Setouchi level. The younger one is the marine and river terraces and "Alluvial deposits" that preserve clear depositional surfaces.

a) The Second Setouchi Supergroup

The second Setouchi Supergroup is composed of the Osaka, Kobiwako, Agé, Tokoname and Seto Groups distributed from west to east.

OSAKA GROUP

Around Osaka Bay and in Kyoto-Nara Basin, there are unconsolidated gravel, sand and mud deposits more than 800 meters in thickness. They are collectively called the Osaka Group. There are marine clay beds of 11 horizons, called Ma 0, Ma 1, ..., and Ma 10 (YOSHIKAWA, 1973) in ascending order and more than 40 layers of thin volcanic ash in this group (YOSHIKAWA, 1976).

KOBIWAKO GROUP

The Kobiwako Group is distributed in the Omi and Iga Basins. It is composed of fresh-water muds, sands, etc., and contains more than 45 layers of thin volcanic ash and pumice (ISHIDA and YOKOYAMA, 1969, HAYASHI, 1974, etc.).

AGÉ, TOKONAME and SETO GROUPS

These are distributed around Ise Bay, and are also composed of fresh-water deposits. More than 30 layers of volcanic ash and pumice are intercalated (YOKOYAMA, 1971, ITOIGAWA, 1971, MORI, 1971a and b, MAKINOUCHI, 1975a and b, 1976, etc.).

The tephrochronologic correlation among these five groups was attempted by several workers (TAKAYA, 1963, YOKOYAMA, 1971 and MORI, 1971a). The results are summarized in Fig. 2, but there still remain many uncertain points to be examined (RESEARCH GROUP FOR CENOZOIC STRATA IN KINKI AND TOKAI DISTRICTS, 1973).

b) Terraces and "Alluvial Deposits"

Terraces are divided into three groups, *i.e.* the high, middle and low ones, by means of the height of the depositional surface, the degree of the surface dissection, the thickness of the reddish soil, the degree of the weathering, the sedimentary environment, *e.g.* marine or fluviatile, and the absolute ages.

ITIHARA (1960) recognized three terraces around Osaka Bay. The sediments of higher one, such as the Shinodayama Formation, are covered with red soil and hardly preserve the depositional surface. The middle-terrace deposits, such as the Uemachi and Nishiyagi Formations, have the intercalation of a marine clay bed and are covered with the yellow soil. The lower terrace deposits, such as the Itami and Tonda For-

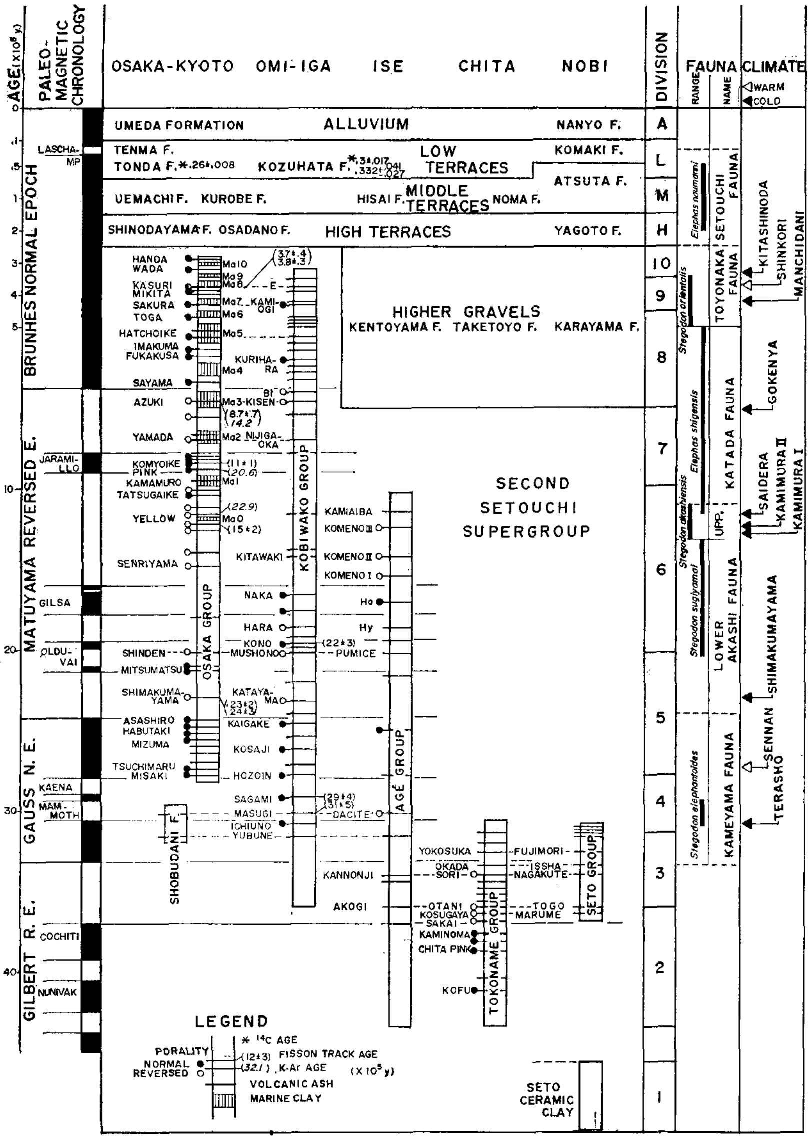

Fig. 2. Stratigraphy in Kinki and Tokai districts.
Stratigraphy: after Ishida and Yokoyama, 1969, Itihara, 1960, Itihara *et al.*, 1975, Itoigawa, 1971, Makinouchi, 1975a, b and 1976; Mori, 1971a and b, Nagoya Group, 1969, Yokoyama, 1969, Yoshikawa, 1973, etc.
Porality: after Ishida *et al.*, 1969, Otofuji *et al.*, 1976 and Torii *et al.*, 1974.
Fission-Track Age: after Nishimura and Sasajima, 1970.
K-Ar Age: after Itihara and Kamei, 1970. ^{14}C Age: after Itihara and Kigoshi, 1962, etc.
Fauna; Range: after Ikebe, 1956, Ikebe *et al.*, 1971, etc.
Name: after Itihara and Kamei, 1970. Climate: after Ishida, 1972, etc.

mations, form the river terrace, and scarcely suffer the weathering and the surface dissection.

On the other hand, a towfold division of terraces was proposed by OKA (1961 and 1963). From the geomorphologic points of view, he considered that the ITIHARA's middle terrace contains two kinds of terraces, one belong to the high terrace and the other to the low terrace (MIZUYAMA *et al.*, 1967). It was difficult to correlate the terrace deposits due to the lack of absolute ages and key beds such as volcanic ash layers in these districts. More detailed works are required to clarify the terrace division, hence the ITIHARA's subdivision is adopted in this paper for the time being.

The Kentoyama (KIMURA and TAKEHARA, 1969), Karayama and Yagoto (NAGOYA GROUP, 1969), and Taketoyo Formations (MAKINOUCHI, 1975b and 1976) are distributed around Ise Bay, where they lie unconformably on the second Setouchi Supergroup. These deposits do not preserve the depositional surface and are situated at higher level. Therefore, they are probably older than the high terrace deposits, but judging from the contained plant remains (ARAKI and KITAMURA, 1971) and pollen spectra (SOHMA, 1958), these deposits may not be so old as the lower part of the Osaka Group (NISHIYAMA *et al.*, 1975 and MAKINOUCHI, 1976).

There distribute the so-called "Alluvial deposits" beneath the alluvial plains of the coastal regions and the inland basins. By means of the radiocarbon measurements, it is clarified that the "Alluvial deposits" are referred to contain the uppermost Pleistocene and Holocene.

Throughout the upper Cenozoic strata in Kinki and Tokai districts, 14 stratigraphic divisions can be distinguished, as shown in Fig. 2, such as 1–10, H, M, L, and A in ascending order.

c) Faunal Succession

The localities and the stratigraphic horizons of the proboscidean fossils in Kinki district were summarized by IKEBE (1959). Several new discoveries and some determinations of the horizon of ever known fossils were added (IKEBE *et al.*, 1966 and 1971, KINKI GROUP, 1969 and MOROZUMI, 1971). In total, 45 localities are known at present. The time range of each species is shown in Fig. 2.

The Pliocene and Pleistocene vertebrate faunas are summarized and classified into the following 6 faunas by ITIHARA and KAMEI (1970) and KAMEI and SETOGUCHI (1970).

1) Kameyama Fauna; represented by *Stegodon* cf. *elephantoides*, that is a element of the Indo-Malayan Faunal Complex.

2) Lower Akashi Fauna; containing *Stegodon sugiyamai*, *Metaplatyceros sequoiae* and *Elaphurus* (?).

3) Upper Akashi Fauna; containing *Stegodon akashiensis*, *Elaphurus akashiensis*, *Cervus* (*Deperetia*) and *Rusa*. The lower and upper Akashi Faunas are considered to be the mixed faunas of the Indo-Malayan Faunal Complex and the Nihowan Fauna

in South China.

4) Katada Fauna; represented by *Elephas shigensis* and containing *Cervus* cf. *elaphus* and Crocodilia, having the elements of Chouk'outien Fauna of North China.

5) Toyonaka Fauna; containing *Stegodon orientalis* and *Tomistoma machikanense*, and considered to have the elements of Wanhsien Fauna of South China.

6) Setouchi Fauna; represented by *Elephas naumanni*, that is the element of Huangt'n Fauna in North China.

d) Floral Changes and Climatic Oscillation

From the view points of the frequencies of the extinct and exotic genera and species, Miki (1948) proposed the several "Plant Beds", such as the *Pinus trifolia* bed, the *Metasequoia* bed, and so on. He added some other beds in consequence of new discoveries. His recent division (Miki, *et al.*, 1962) is shown in Fig. 3.

The definition of the *Metasequoia* flora was given by Itihara (1960 and 1961). He called the flora of the lower and lowermost parts of the Osaka Group, that had been named as "*Metasequoia* and its associated plants" by Huzita (1954), as the "*Metasequoia* flora". And taking the notice of difference of the specific composition, he distinguished two floral types, one is that of flourishing age of the *Metasequoia* flora and the other is that of extinction of that flora. He also discussed the Plio-Pleistocene boundary following the recommendation of IGC at London 1948, and concluded that this

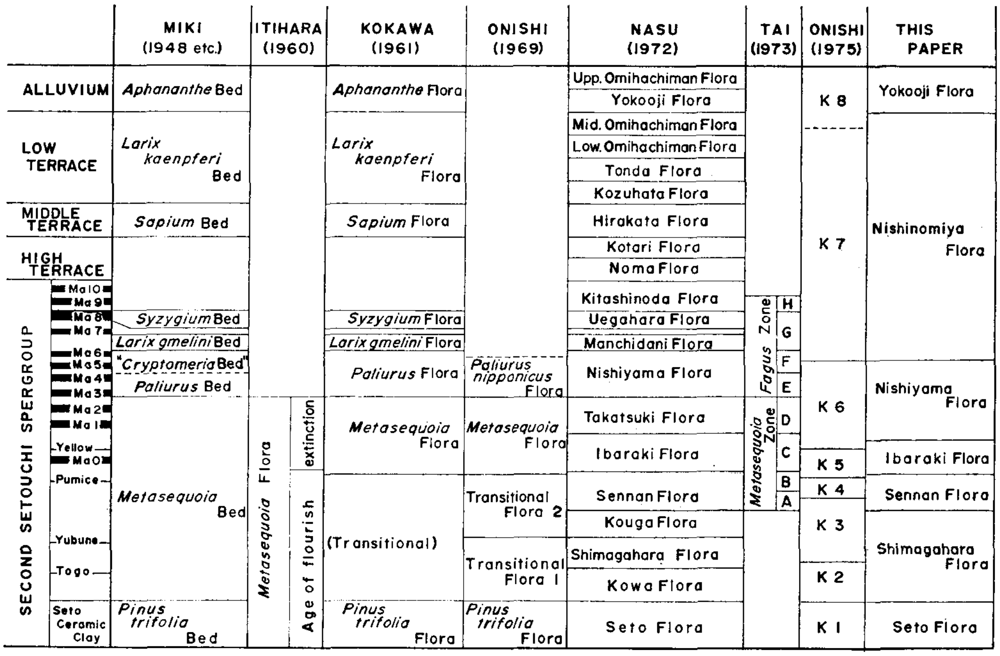

Fig. 3. Floral subdivisions in Kinki and Tokai Districts. (modified from Onishi, 1975).

boundary may be correlated to the boundary between the two types of the *Metasequoia* flora.

The floras from the MIKI's plant beds are called by floral names by KOKAWA (1961), for example the flora from the *Pinus trifolia* bed as the *Pinus trifolia* flora, excepting the *Metasequoia* bed, in which he distinguished two floras, the *Metasequoia* flora, above, and the Transitional one, below.

Succeeding to him, the writer asserted that his Transitional flora should be divided into two types (ONISHI, 1969b).

Another floral succession was proposed by NASU (1972). Mainly based on the stratigraphic horizon, he distinguished twenty floras in the Pliocene and Pleistocene, such as the Seto flora, the Kowa flora and so on (Fig. 3).

From pollen analytical studies, TAI (1963) divided the Osaka Group into two pollen zones; the *Metasequoia* and *Fagus* zones. After several attempts for subdivision of her pollen zones, she (1973) finally proposed 8 subzones, named as A, B, C, ..., and H subzones in ascending order (Fig. 3).

The age names of the cold and warm horizons that were previously reported by many workers were given by ISHIDA *et al.* (1969). Recently, some ages were added (ISHIDA, 1972 and KOMYOIKE RESEARCH GROUP, 1971) as shown in Fig. 2.

The detailed discussions on these problems will be given in the later section.

e) Paleomagnetism and Absolute Ages

The directions of natural remanent magnetizations of volcanic ash layers of the second Setouchi Supergroup were measured by ISHIDA *et al.* (1969). At least 10 geomagnetic polarity changes and three prevalent groups which were correlated with the Brunhes normal, Matuyama reversed, and Gauss normal epochs in descending order were recognized (Fig. 2).

Magnetostratigraphy of the Osaka Group in Sennan-Senpoku area has been studied by TORII *et al.* (1974). The result is shown in Fig. 2.

Recently, the magnetizations of several volcanic layers of the Tokoname Group in Chita Peninsula are reported (OTOFUJI *et al.*, 1976). The upper half of this group shows the reversed polarity and the lower half shows the normal polarity. As the Gauss epoch may be recognized in the lower part of the Kobiwako Group (ISHIDA *et al.*, 1969), this polarity change may be correlated to the Gilbert epoch.

K-Ar ages of some volcanic ash layers were measured by KANEKO *et al.* (ITIHARA and KAMEI, 1970). The results are shown in Fig. 2.

Fission-track ages of zircon, hornblende and anthophillite were measured by NISHIMURA and SASAJIMA (1970), and the results were said to agree well with the paleomagnetic ages proposed by ISHIDA *et al.* (1969) (Fig. 2).

Radiocarbon ages of the terrace and Alluvial deposits were also obtained by many workers (for example, ITIHARA and KIGOSHI, 1962, ITIHARA and TAKAYA, 1965, and ISHIDA *et al.*, 1969). These are also shown in Fig. 2.

B. Floral succession

In Kinki and Tokai districts, 382 species belonging to 201 genera and 84 families of plant fossils were reported by MIKI, KOKAWA and others. These plant fossils involve not only the species living in Japan, the indigenous species, but also those already disappeared from Japan, the exotic and extinct species. In the indigenous species, there are four climatic groups, such as subtropic, warm temperate, cool temperate, and subalpine (or subarctic) elements.

The climatic zones used in this paper are as follows:

Subalpine (or Subarctic) zone is represented by evergreen conifer forest trees, such as *Picea jezoensis*, *Abies veitchii*, *A. mariesii*, *A. sachalinensis*, *Pinus koraiensis*, and *Tsuga diversifolia*.

Cool temperate zone is represented by decidious broad-leaved forest trees, such as *Fagus crenata*, *Quercus crispra*, etc.

Warm temperate zone is represented by evergreen broad-leaved forest trees, such as *Cyclobalanopsis* spp., *Castanopsis cuspidata*, and *Machilus japonica*.

Subtropic zone is represented by evergreen broad-leaved forest trees and mangrove.

Stratigraphic distribution of the Pliocene and Pleistocene macrofloras in Kinki and Tokai districts are shown in Fig. 4 and Appendix.

Several floral subdivisions were already proposed by several workers (Fig. 3). In these geofloras, the following 7 floras have the distinctive features.

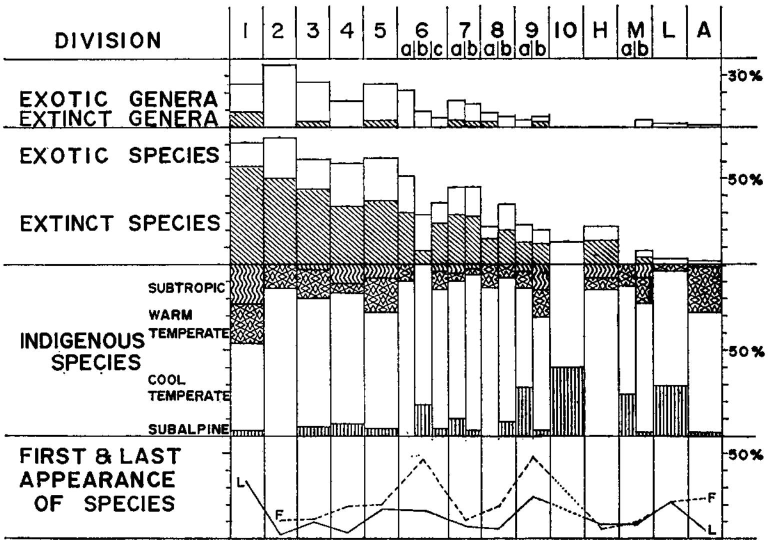

Fig. 4. Floral changes in Kinkk and Toiai districts.
Division 6; a: lowest part, b: Kamimura cold ages, c: the other part.
Divisions 7 to 9 and M; a: non-marine facies, b: marine facies.

1) Seto Flora (NASU, 1972)

From the Seto ceramic clay bed, 116 species belonging to 89 genera of plant remains were already reported (MIKI, 1941a, 1963, etc.). Among these fossils, about 25% of genera are extinct (ca. 9%) or exotic (ca. 16%) and about 70% of species are extinct (ca. 57%) or exotic (ca. 14%). Moreover, 36 species, such as *Pinus trifolia, Protosequoia primarium, Eotrapa tetrasepla,* disappeared at this horizon (Division 1). In the indigenous species, about a half are the subtropic or warm temperate elements, so the oceanic warm climate is supposed during that time (MIKI, 1963). This flora is called the *Pinus trifolia* (KOKAWA, 1961) or the Seto flora (NASU, 1972).

2) Shimagahara Flora (NASU, 1972)

The flora of the lowest part of the Kobiwako Group (Division 3) is characterized by a few percent of extinct genera (ca. 3%) and by maximum percentage of the last appearance of species. This flora contains *Carya striata* and *Nyssa* spp., and corresponds to the Transitional flora 1 (ONISHI, 1969b). NASU (1972) called this flora as the Shimagahara flora.

3) Sennan Flora (NASU, 1972)

In Sennan area, the peculiar plant remains, such as *Ginkgo biloba* and *Taiwania cryptomerioides*, are reported (HIKITA, 1949, MIKI, 1955a, etc.) from the lowermost part of the Osaka Group (Division 5). The flora of this division is called the Transitional flora 2 (ONISHI, 1969b) or the Sennan flora (NASU, 1972). This flora contains 67 species belonging to 57 genera of plant fossils and has a high percentage of exotic and extinct genera (ca. 25%).

4) Ibaraki Flora (NASU, 1972)

From Ma 0 (Division 6), the exotic or extinct species, such as *Metasequoia disticha, Cunninghamia konishii, Picea koribai, Thuja koraiensis, Pterocarya paliurus, Zelkova ungerii,* etc., are reported (MIKI, 1937, etc.) and these assemblage is named the *Metasequoia* flora by KOKAWA (1961) or the Ibaraki flora by NASU (1972). This flora contains rather low percentage of exotic genera or exotic and extinct species and shows high percentage of the first appearance of species.

5) Nishiyama Flora (NASU, 1972)

The flora obtained from Division 8 is characterized by a few percent of extinct genera. This flora contains such extinct and exotic species as *Paliurus nipponicus* and *Sapium sebiferum* and called the *Paliurus* flora (KOKAWA, 1961) or the Nishiyama flora (NASU, 1972).

6) Nishinomiya Flora

The flora obtained from Division 9 is named here the Nishinomiya flora. This flora contains two types, one is a cold type and the other warm. The cold type is called the *Larix gmerini* flora (KOKAWA, 1961) or the Manchidani flora (NASU, 1972) and the warm type is called the *Syzygium* flora (KOKAWA, 1961) or the Uegahara flora (NASU, 1972).

The *Larix gmerini* flora is reported from Manchidani in Nishinomiya City (MIKI, 1941b). This is a peculiar flora containing about 55 percent of subalpine conifer forest elements. And it is estimated to represent the coldest climate in the Osaka Group (ISHIDA, 1972).

The *Syzygium* flora is reported from Uegahara in Nishinomiya City (MIKI *et al.*, 1957) and Hirakata City (TAKAYA and ITIHARA, 1961 and ITIHARA *et al.*, 1966). This flora is characterized by the abundance of evergreen broad-leaved trees. It is remarkable that this flora contains about 18 percent of subtropic elements represented by the species now living in more south than southern Kyushu, such as *Syzygium buxifolium*, *Cinnamomum doederleinii*, *C. daphnoides*, and about 23 percent of warm temperate elements.

7) Yokooji Flora (NASU, 1972)

This flora contains evergreen broad-leaved trees as *Camellia japonica*, *Castanopsis cuspidata*, *Cyclobalanopsis* spp. (MIKI, 1948, etc.). Temperate conifer and deciduous broad-leaved trees are also contained. This is called the *Aphananthe* flora (KOKAWA, 1961), the *Castanopsis* flora (MIKI *et al.*, 1962) or the Yokooji flora (NASU, 1972).

C. Pollen assemblages and pollen zones

Pollen analyses were carried out on the samples obtained from 23 localities which covered almost all horizons of the Pliocene and Pleistocene deposits in Kinki and Tokai districts. The pollen diagrams published by the writer (ONISHI, 1975) are reproduced in Fig. 6 to Fig. 9. Based on the feature of each pollen spectrum, following 14 pollen assemblages were proposed. The representative spectrums are also shown in parenthesis.

1) *Cyclobalanopsis-Carya* assemblage (ST-1 and 2)
2) *Cyclobalanopsis-Podocarpus* assemblage (H 1 in TAI (1963))
3) *Cyclobalanopsis-Abies* assemblage (Fus-5, 9 and 15)
4) *Quercus-Liquidambar* assemblage (Kog-3, 7 and 9)
5) *Quercus*-Taxodiaceae assemblage (Kog-10 and 11)
6) *Fagus-Quercus* assemblage (Kar-1-1 to 2–5)
7) Taxodiaceae-*Zelkova* assemblage (Sen-5)
8) *Metasequoia-Picea* A assemblage (Sen-8 and 9)
9) *Fagus-Nyssa* assemblage (SK-1 to 3)
10) *Fagus-Cryptomeria* assemblage (Kar-3-1 to 3–4)
11) *Fagus-Tsuga* assemblage (Kar-5–3)
12) *Diploxylon-Cryptomeria* assemblage (Fus-18 and 19)
13) *Picea-Cryptomeria* assemblage (Hir-1 and Gum-1)
14) *Picea-Haploxylon* assemblage (Nis-1 to 4)

Judging from the contained taxa and the stratigraphic horizon, some pollen assemblages are connected with the above-mentioned macrofloras as follows (ONISHI, 1975).

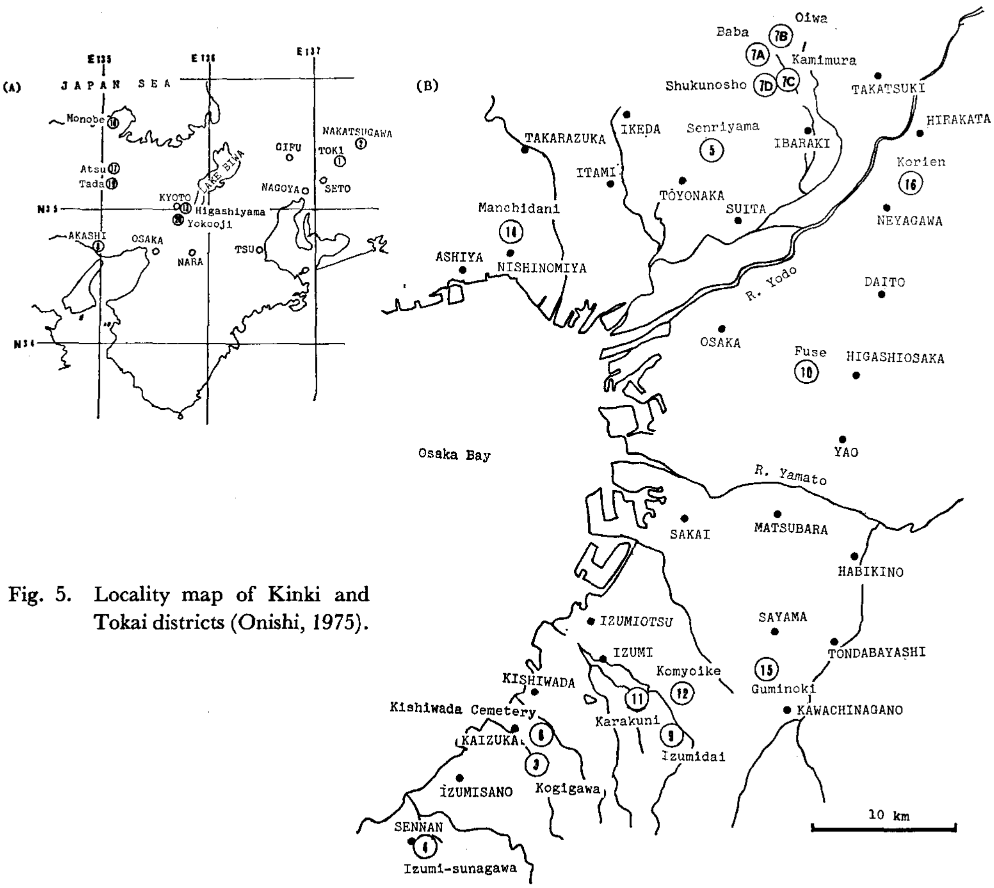

Fig. 5. Locality map of Kinki and Tokai districts (Onishi, 1975).

Cyclobalanopsis-Carya assemblage — Seto flora
Cyclobalanopsis-Podocarpus assemblage — *Syzygium* flora
Cyclobalanopsis-Abies assemblage — Yokooji flora
Quercus-Liquidambar assemblage — Sennan flora
Metasequoia-Picea A assemblage — Ibalaki flora
Fagus-Nyssa assemblage — Shimagahara flora

Based on the stratigraphic distribution of these pollen assemblages, 8 pollen zones, K 1 to K 8 in ascending order, were distinguished (Onishi, 1975).

Zone K 1

Zone K 1 is characterized by the *Cyclobalanopsis-Carya* assemblage.

Zone K 2

This zone is characterized by the *Fagus-Nyssa* assemblage.

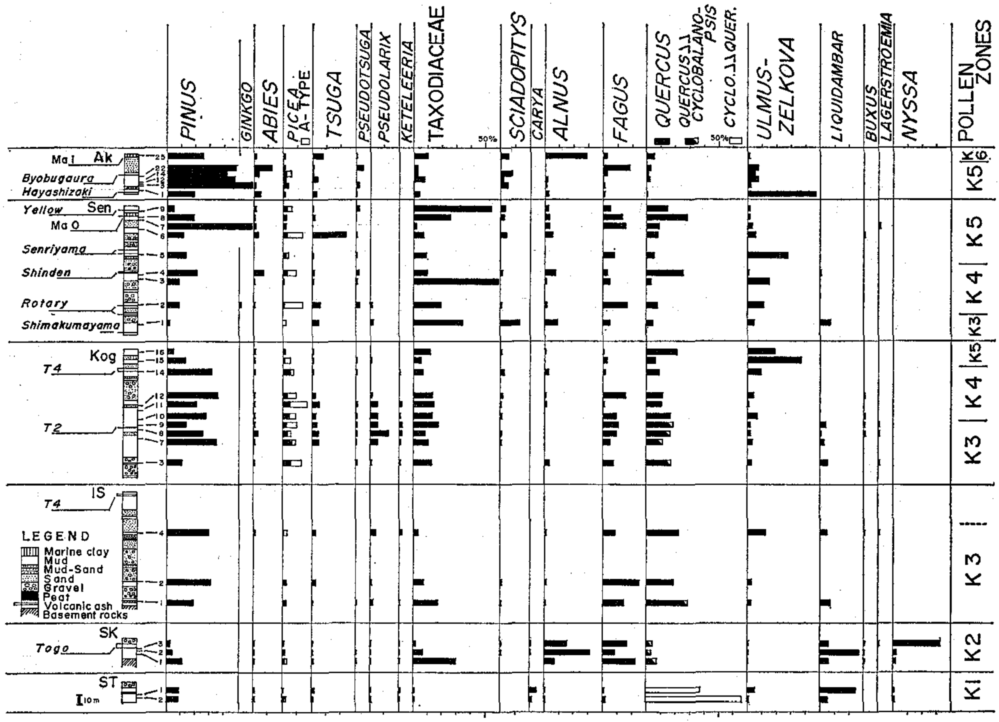

Fig. 6. Pollen diagram in Kinki and Tokai districts (I) (modified from Onishi, 1975).
Ak: Akashi, Sen: Senriyama, Kog: Kogigawa, IS: Izumisunagawa, SK: Nakatsugawa, ST: Toki.

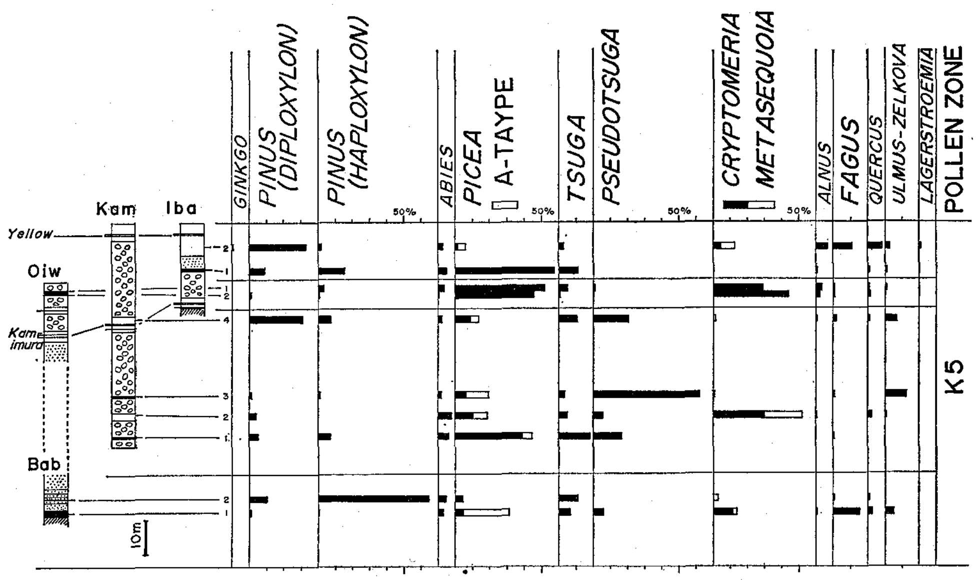

Fig. 7. Pollen diagram in Kinki and Tokai districts (II) (modified from Onishi, 1975).
Kam: Kamimura, Iba: Shukunosho, Oiw: Oiwa, Bab: Baba.

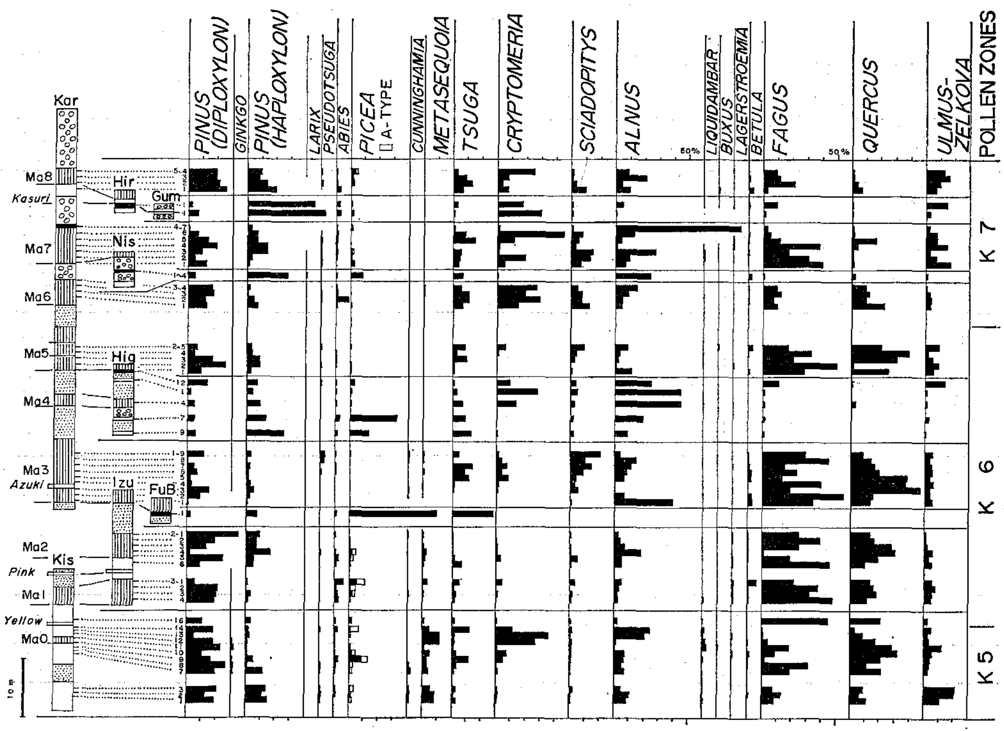

Fig. 8. Pollen diagram in Kinki and Tokai districts (III) (modified from Onishi, 1975).
Kar: Karakuni, Hir: Korien, Gum: Guminoki, Nis: Manchidani, Hig: Higashiyama, Izu: Izumidai, Kis: Kishiwada Cemetery.

Zone K 3

This zone is characterized by the *Quercus-Liquidambar* assemblage.

Zone K 4

This zone is characterized by the *Quercus*-Taxodiaceae and Taxodiaceae-*Zelkova* assemblages.

Zone K 5

This zone is characterized by the *Metasequoia-Picea* A assemblage. The *Picea-Haploxylon*, *Picea-Cryptomeria* and *Fagus-Quercus* assemblages also occur in this zone.

Zone K 6

This zone is marked by the *Fagus-Quercus* assemblage. The *Fagus-Cryptomeria* and *Picea-Haploxylon* assemblages are accompanied in this zone.

Zone K 7

This zone is characterized by *Fagus-Cryptomeria* assemblage. The *Cyclobalanopsis-Podocarpus*, *Fagus-Quercus*, *Fagus-Tsuga*, *Picea-Cryptomeria*, and *Picea-Haploxylon* assemblages also occur in this zone.

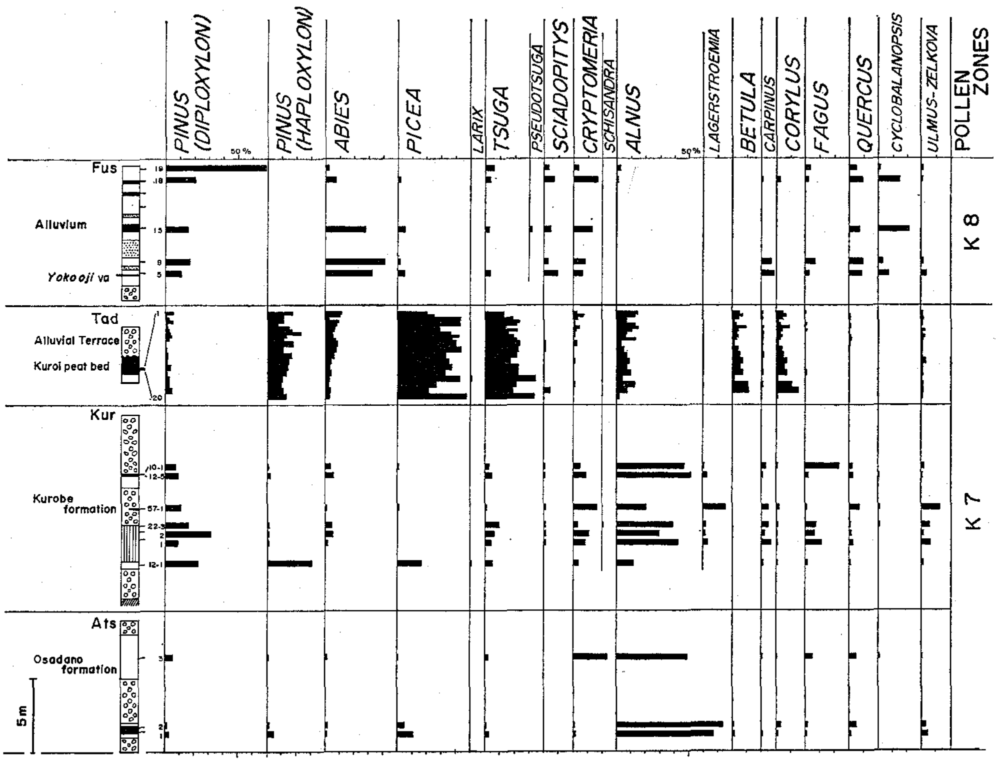

Fig. 9. Pollen diagram in Kinki and Tokai districts (IV) (modified from Onishi, 1974 and 1975). Fus: Yokooji, Tad: Tada, Kur: Monobe, Ats: Atsu.

Zone K 8

Zone K 8 is characterized by the *Cyclobalanopsis-Abies* assemblage. The *Diploxylon-Cryptomeria* assemblage appears at the upper part of this zone.

III. Pollen Analysis of the other Districts

Pollen data have been obtained from the following five districts in southwestern and central Japan (Fig. 1).

A: Oita district
B: San'in district
C: Hokuriku district
D: Kanto district
E: Niigata district

A. Oita District

Stratigraphic notes:

The upper Cenozoic System in Oita district was studied by SHUTO (1953 and

1962, and SHUTO *et al.*, 1966). Several revisions were proposed by NORTH KYUSHU RESEARCH GROUP (ISHIDA *et al.*, 1970) as follows:

1) The boundary between the SHUTO's Sekinan and Oita Groups is not unconformity. It means that it is not necessary to divide the upper Cenozoic into two groups.

2) The SHUTO's Handa Formation is coeval with the Higashiwasada Formation.

3) The Ozai Formation is not the terrace deposits but the uppermost part of the Oita Group.

The Oita Group is then subdivided into three formations as shown in Fig. 10.

Recently, OKAGUCHI (1976) published a geological map of Tsurusaki Hills and fission-track ages of the Shikido (=Shikito) and Hada (=Haneda) Ash Flows as shown in Fig. 10. But these absolute ages do not agree with the macro- and microfloral succession in this district.

The middle-terrace Deposits, called the Oka Formation, intercalate a marine clay bed (SHUTO *et al.*, 1966) and two units of pumice flow deposits. The pumice flows are called the Nakayasu and Ichigi pumice flows (SHUTO *et al.*, 1966) in ascending order. These pumice flows are correlated respectively to "Aso 3" and "Aso 4" (ONO, 1965 and WATANABE and ONO, 1969) by means of the heavy mineral composition.

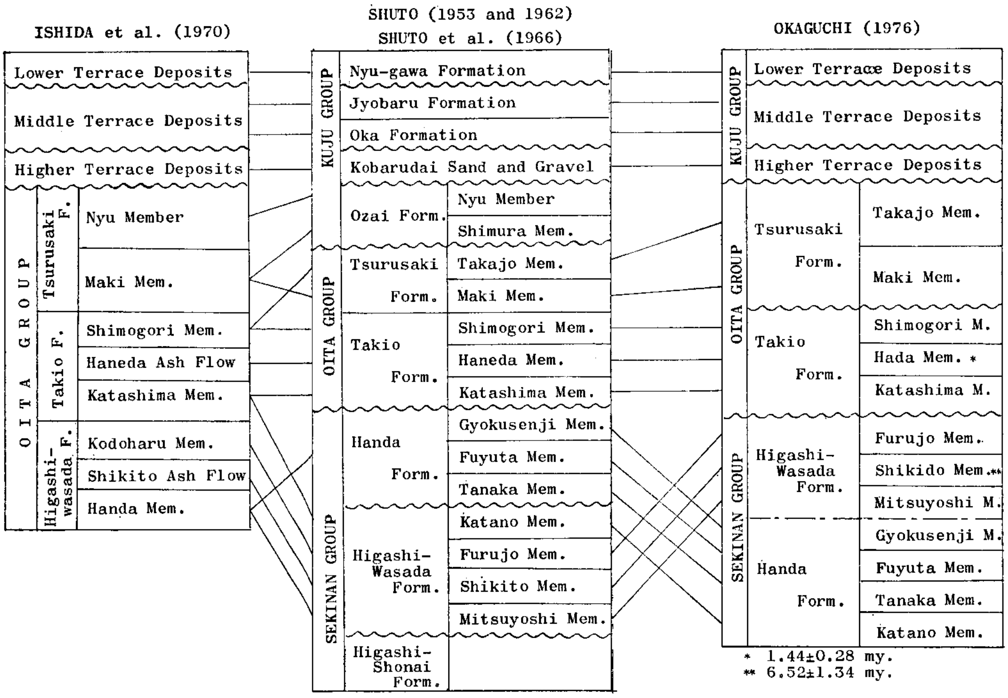

Fig. 10. Stratigraphy in Oita district.

"Aso 4" corresponds to the Yame "Clay" on which ¹⁴C-age of 33,000+3,000, −2,000 years B.P. (GaK-282) was measured (Ariake Bay Research Group, 1969).

Fossils:

Stegodon orientalis was reported from the Maki Member (Shuto, 1953 and Okaguchi, 1976).

Plant fossils are summarized as follows:

1) The Handa Member (Shuto, 1953)

Metasequoia disticha, *Zelkova ungerii*, *Ilex cornuta*, etc.

2) The Shikito Member (Shuto, 1953)

Fagus ferruginea, *Zelkova ungerii*, *Fagara ailantoides*, etc.

3) The Nyu Member

Juglans sieboldiana, *Alnus* sp. and *Zelkova* sp. (collected by North Kyushu Research Group)

Vitex rotundifolia, *Sapium sebiferum* var. and *Corylus heterophylla* (collected by the writer)

4) The Oka Formation (collected by the writer)

Styrax japonica, *Sapium sebiferum* var., *Lagerstroemia* sp. and *Aleurites cordata*.

Pollen data:

A pollen diagram of the Oita Group based on the Shuto's stratigraphy was presented by the writer (1965), but, recently, the stratigraphy was corrected by North Kyushu Research Group (Ishida *et al.*, 1970). A pollen diagram based on the new stratigraphy is shown in Fig. 12. Several samples (64-111, 112 and 113) were collected from the Higashishonai Formation, of which relation to the Oita Group is yet uncertain.

Pollen Assemblages

Three pollen assemblages can be distinguished in the horizons lower than the Shikito Ash Flow.

1) The *Quercus*-Taxodiaceae assemblage (64-113 and 111-2) is characterized

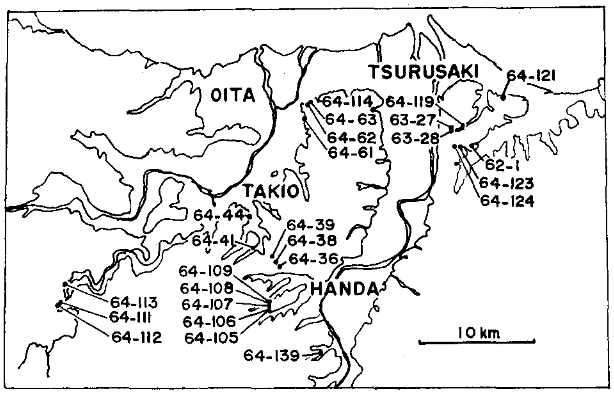

Fig. 11. Locality map of Oita district (modified from Onishi, 1965).

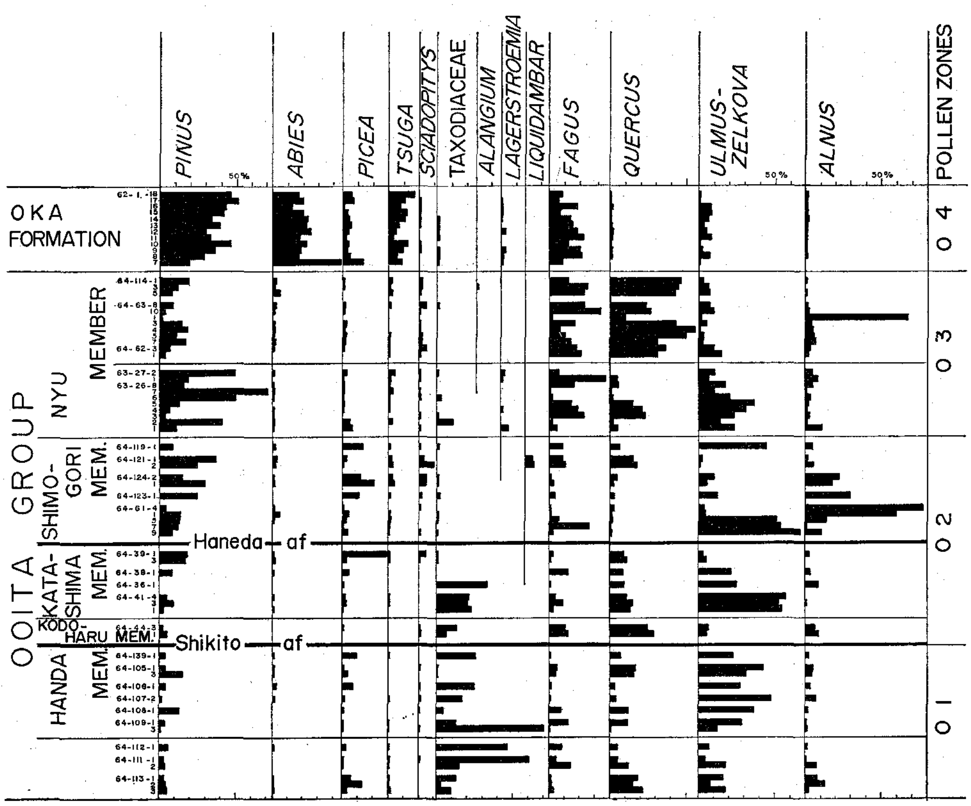

Fig. 12. Pollen diagram in Oita district (modified from Onishi, 1965).

by high frequencies of *Quercus* and Taxodiaceae.

2) The *Metasequoia-Picea* A assemblage (64-111-1, 112, and 109-3) is predominant in Taxodiaceae including *Metasequoia* and accompanied by *Fagus*, *Quercus* and *Ulmus-Zelkova*.

3) The Taxodiaceae-*Zelkova* assemblage (64-109-1, 108, 107, 106, 105, and 139) is predominant in *Ulmus-Zelkova* and accompanied by Taxodiaceae and *Quercus*.

Three pollen assemblages are recognized between the Shikito and Haneda Ash Flows.

1) The *Fagus-Quercus* assemblage (64-44 and 39-1) has dominant pollen of *Fagus* and *Quercus*, and is accompanied by Taxodiaceae, *Carpinus*, etc.

2) The *Ulmus-Zelkova* assemblage (64-36, 38-1 and 41) is characterized by a predominance of *Ulmus-Zelkova* with a few pollen of *Fagus* and *Quercus*.

3) The *Picea-Haploxylon* assemblage (64-39-1) is characteristic of a high percentage of *Picea* and *Pinus* including *Haploxylon*.

Three pollen assemblages are recognized above the Haneda Ash Flow.

1) The *Ulmus-Zelkova* assemblage (64-61-5, 7, 9 and 119-1) is marked by a predominance of *Ulmus-Zelkova* with a few pollen of Taxodiaceae or *Quercus*.

2) The *Fagus-Quercus* assemblage (64-121, 62, 63, 114, 63-26, and 27) is characterized by a high percentage of *Fagus* and *Quercus*, and accompanied by *Carpinus* and *Ulmus-Zelkova*.

3) The *Picea-Haploxylon* assemblage (64-124 and 123) is rich in *Pinus*, *Picea* and *Alnus* pollen grains.

The Oka Formation is characterized by the *Fagus-Tsuga* assemblage. The spectrum is marked by a high percentage of conifers such as *Pinus*, *Abies* and *Tsuga*. *Fagus* and *Ulmus-Zelkova* pollen grains are also abundant. The stable occurrence of *Lagerstroemia* shows that this conifer forest may be the temperate one.

Pollen Zones and Correlation:

Four pollen zones can be distinguished in this district, that is, zone O 1 to O 4 in ascending order.

Zone O 1

Below the Shikito Ash Flow is zone O 1. It is characterized by the *Metasequoia-Picea* A and Taxodiaceae-*Zelkova* assemblages. These assemblages lead us to correlate zone O 1 to zone K 5 of Kinki district.

Zone O 2

From the Shikito Ash Flow to the top of the Shimogori Member is zone O 2. This zone is marked by the *Ulmus-Zelkova*, *Fagus-Quercus* and *Picea-Haploxylon* assemblages. This zone may be correlated to zone K 6, as there is a similarity of pollen assemblage in these zones.

Zone O 3

The Nyu Member corresponda to zone O 3, consisting of marine clays and freshwater sands and muds. It is characterized by the *Fagus-Quercus* assemblage. As will be mentioned in the next chapter, the *Fagus-Quercus* assemblage indicates a somewhat warmer climate than the *Fagus-Cryptomeria* assemblage, so this zone may be correlative to zone K 7 in spite of the low frequency of *Cryptomeria*.

Zone O 4

The Oka Formation corresponds to zone O 4. It is marked by the *Fagus-Tsuga* assemblage. This zone is correlated to zone K 7 by the reason of the similarity of pollen assemblage and its stratigraphic position.

B. San'in District

The Pliocene and Pleistocene Series in San'in district is divided into two units. The older one is the Plio-Pleistocene Tsunozu Group and the younger includes the middle and upper Pleistocene and Holocene deposits.

a) The Tsunozu Group

The Tsunozu Group has four marine clay beds, named as M 1, M 2, M 3, and M 4 in ascending order, and a thin volcanic ash layer called "Jelly Tuff" at a horizon

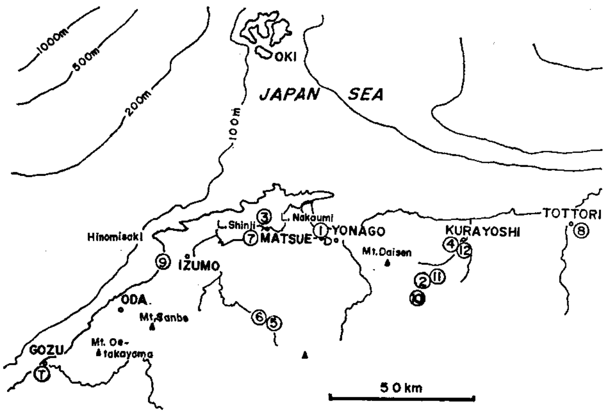

Fig. 13. Locality map of San'in district.
T: Tsunozu
1: Nakaumi 2: Hanazono 3: Okudani 4: Shuki 5: Yokota 6: Omagari 7: Yumachi
8: Tsunoi 9: Sashimi 10: Kuroiwa 11: Hanazono 12: Minatomachi

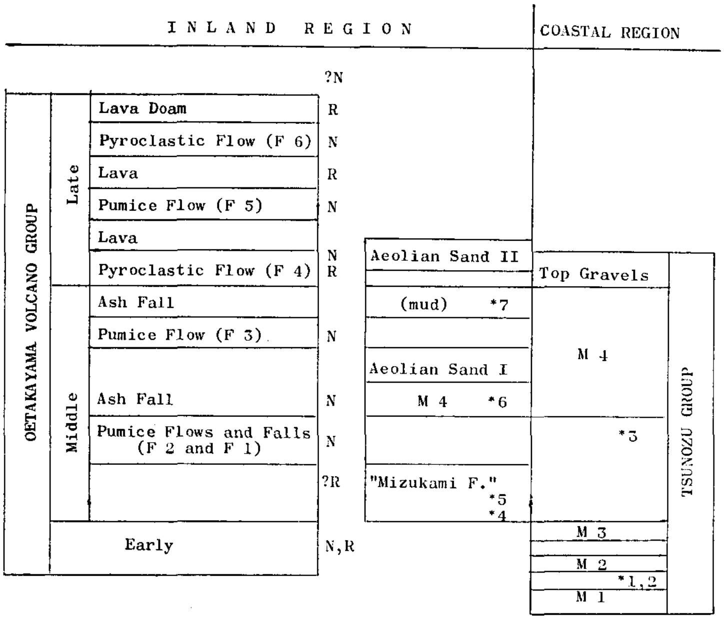

Fig. 14. Stratigraphy of the Tsunozu Group.
Inland region (San'in Quaternary Research Group, 1973)
Coastal region (Onishi and Choshi, 1970)
N, R: polarity (modified from Fukuma, 1972)
*1-*7: fossil horizons

between M 1 and M 2 (SAN'IN QUATERNARY RESEARCH GROUP, 1969 and ONISHI and CHOSHI, 1970). The uppermost marine clay bed, M 4, distributes in the inland area where the Oe-Takayama Volcano Group erupted. The stratigraphy of the Tsunozu Group is shown in Fig. 14 (TSUNOZU RESEARCH GROUP, 1972 and SAN'IN QUATERNARY RESEARCH GROUP, 1973).

Fauna and flora:

A fossil Proboscidea, *Stegodon elephantoides* (?), was found from the sand bed between M 1 and M 2 (No. 1 in Fig. 14).

Many plant remains are reported from several localities (Nos. 2 to 7 in Fig. 14).

Below M 2 (No. 2), the following species are found from several localities around Tsunozu and Asari (MIKI, 1950, etc.).

Chephalotaxus obovata, *Keteleeria davidiana*, *Pseudolarix kaempferi*, *Pseudotsuga subrotunda*, *Cunninghamia konishii*, *Glyptostrobus* sp., *Sequoia* sp., *Pterocarya paliurus*, *Liquidambar* sp., *Nyssa pachycarpa*, *Meliodendron xylocarpum*, *M. multistratum*, etc.

From the "Mizukami Formation" at Komatsuji (No. 4, collected by A. ADACHI and M. FURUTANI) and Oe (No. 5).

Picea koribai, *Metasequoia disticha*, *Juglans megacinerea*, *Pterocarya paliurus*, etc.

From M 4 (Nos. 6 and 7) and jast under this bed (No. 3).

Picea koribai, *Metasequoia disticha*, *Cunninghamia konishii*, *Pterocarya* cf. *paliurus*, etc.

Paleomagnetism:

The directions of the natural remanent magnetization of the pyroclastic sediments and lavas of the Oe-takayama Volcano Group were measured by FUKUMA (1972). The result is shown in Fig. 14, after the correction of the stratigraphic horizon. There are at least three times of change from reversal to normal polarities. Judging from faunal and floral data, these cover almost all of the Matuyama reversed epoch.

Pollen data:

Pollen diagrams of the Tsunozu Group were reported by the writer (ONISHI 1969a). The group is subdivided into three pollen zones, here termed as zones T 1 to T 3 (Fig. 15).

Pollen Assemblages

1) *Quercus-Liquidambar* assemblage; almost all samples of zone T 1 belong to this assemblage, except for several spectra that show the predominance of *Alnus*.

2) Taxodiaceae-*Zelkova* assemblage; observed in the upper part of zone T 1.

3) *Quercus*-Taxodiaceae assemblage; all samples of zone T 2 belong to this assemblage.

4) *Metasequoia-Picea* A assemblage; all samples of zone T 3 belong to this assemblage.

Correlation with Kinki District

The same assemblages as those in Kinki district are obtained from the Tsunozu

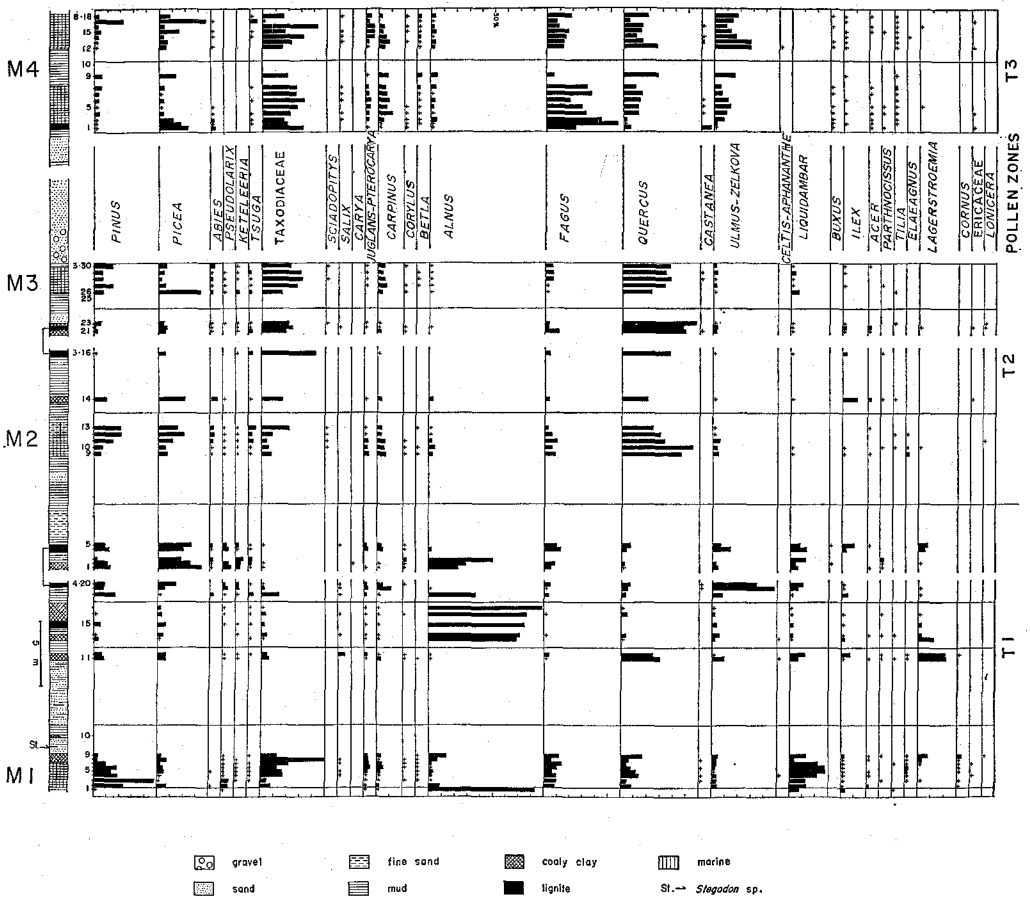

Fig. 15. Pollen diagram of the Tsunozu Group (Onishi, 1969a).

Group. The following correlation is considered to be reasonable.

The Tsunozu Group	The Osaka Group
Zone T 3	Zone K 5
Zone T 2	Zone K 4
Zone T 1	Zone K 3

b) The Middle and Upper Pleistocene and Holocene Deposits

The stratigraphy of the middle and upper Pleistocene and Holocene strata in San'in district was summarized by SAN'IN QUATERNARY RESEARCH GROUP (1969). After then, several works were reported on the areas of Lake Nakaumi (MIZUNO *et al.*, 1972), Izumo (MII and FUJII, 1972a), Yokota (MII and FUJII, 1972b), and Hiruzen-bara (HIRUZEN-BARA RESEARCH GROUP, 1973 and RESEARCH GROUP FOR THE HIRUZEN-

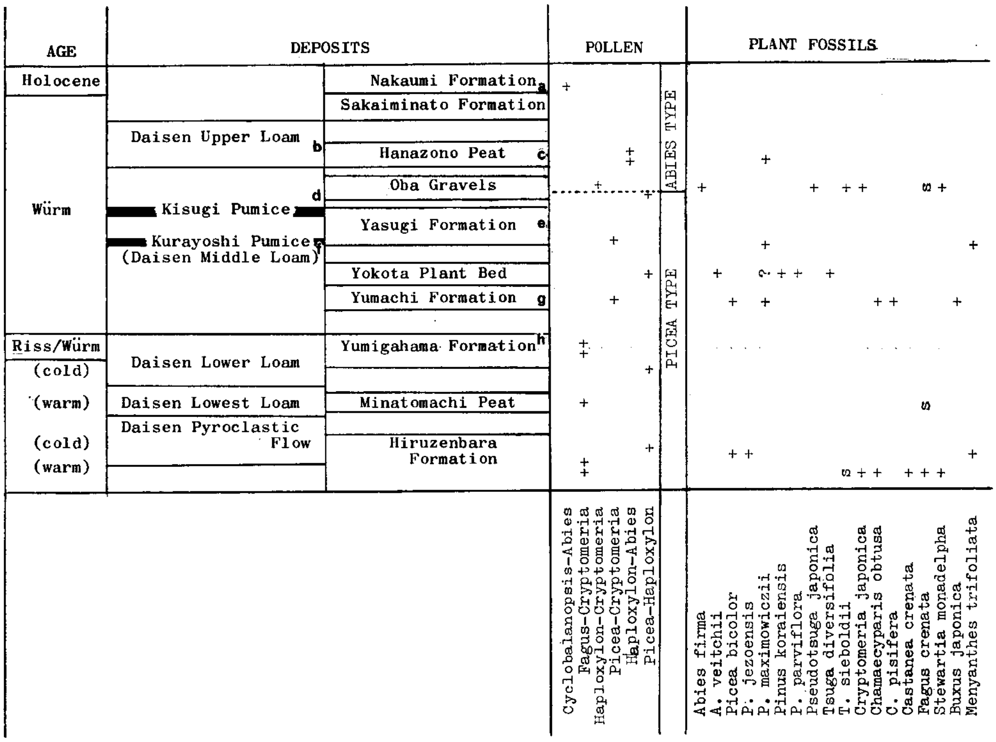

Fig. 16. Stratigraphy of the middle and upper Pleistocene and Holocene deposits in San'in district (after Onishi, 1974).

a–h: ^{14}C ages,

a: 9,820±390 (GaK-2878), Mizuno *et al.* (1972)
b: 17,200±400 (GaK-383), San'in Quaternary Research Group (1969)
c: 21,710±760 (GaK-4033), Hiruzenbara Research Group (1973)
d: 25,600±1,000 (GaK-1533), Suzuki *et al.* (1968)
e: 29,100+2,600 −2,000 (GaK-2270), Mizuno *et al.* (1970)
 >32,800 (GaK-2269), *Ditto*
 >30,600 (GaK-2882), Mizuno *et al* (1972)
 >31,200 (GaK-2885), *Ditto*
f: 30,200±3,500 (GaK-225), San'in Quaternary Research Group (1969)
g: >31,200 (GaK-815), *Ditto*
h: >30,400 (GaK-2886), Mizuno *et al.* (1972)

Plant fossils:

s: Species is not determined, ?: Species is uncertain.

BARA, 1975). Stratigraphy and pollen assemblages in this district are summarized in Fig. 16 (ONISHI, 1974).

Fauna and flora:

Stegodon orientalis is reported from the Hiruzen-bara Formation (RESEARCH GROUP FOR THE HIRUZENBARA, 1975).

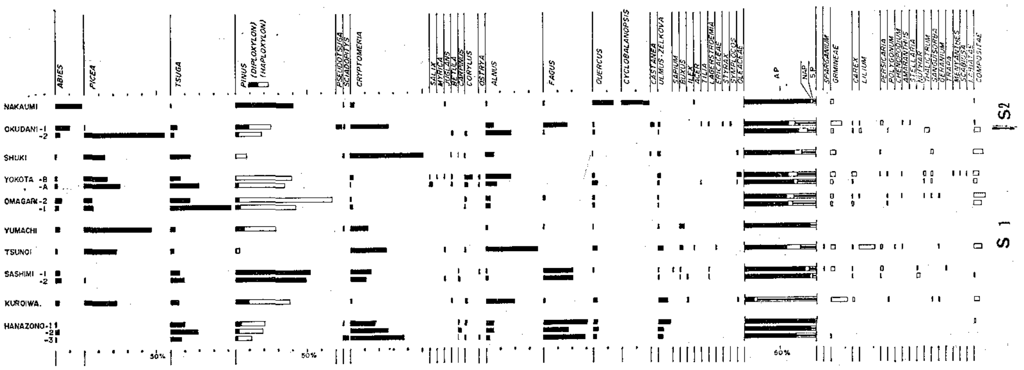

Fig. 17. Pollen diagram of the middle and upper Pleistocene and Holocene deposits in San'in district (Onishi, 1974).

Several teeth of *Elephas naumanni* are discovered from the sea bottom about 200 m. deep off Hinomisaki. The age of these fossils is estimated as the maximum Würm Glaciation (KAMEI, 1967).

Plant fossils are summarized in Fig. 16 (ONISHI, 1974).

Pollen data:

The following 6 pollen assemblages were reported by the writer (ONISHI, 1974).

1) *Cyclobalanopsis-Abies* assemblage (Nakaumi in Fig. 17).

2) *Haploxylon-Abies* assemblage: It is characterized by a high percentage of *Haploxylon, Abies* and *Tsuga*. *Picea* pollen is rare or absent. *Corylus, Betula* and *Myrica* pollen are common (Hanazono-1 to 8 in Fig. 18).

3) *Haploxylon-Cryptomeria* assemblage: The spectrum of Okudani-1 (in Fig. 17) is characterized by a predominance of *Cryptomeria*. *Abies, Haploxylon, Tsuga* and *Fagus* pollen are accompanied, but only few pollen of *Picea* occurs. *Haploxylon-Cryptomeria* assemblage is proposed for this association.

4) *Fagus-Cryptomeria* assemblage (Hanazono-1 to 3 and Sashimi-1 and 2 in Fig. 17).

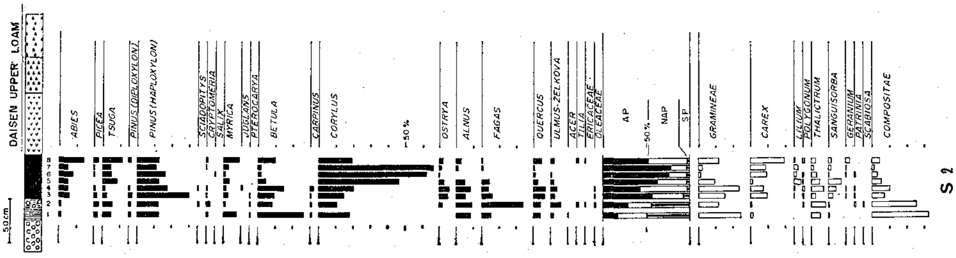

Fig. 18. Pollen diagram of the Hanazono Peat Bed (Onishi, 1974).

5) *Picea-Cryptomeria* assemblage (Shuki, Yumachi and Tsunoi in Fig. 17).

6) *Picea-Haploxylon* assemblage (Okudani-2, Yokota, Omagari and Kuroiwa in Fig. 17).

These pollen assemblages are grouped into two sets of pollen assemblages, *i.e.*, *Abies* type and *Picea* type (Fig. 16). *Abies* type covers the Holocene and the uppermost Pleistocene (about 2.5×10^4 years B.P. to present) and *Picea* type covers the upper and middle Pleistocene (ONISHI, 1974). The zones that are represented by these two types are termed zones S 2 and S 1, respectively.

Zones	S 2	S 1
Types	*Abies* Type	*Picea* Type
warm	*Cyclobalanopsis-Abies* assemblage	*Fagus-Cryptomeria* assemblage
↕	*Haploxylon-Cryptomeria* assemblage	*Picea-Cryptomeria* assemblage
cold	*Haploxylon-Abies* assemblage	*Picea-Haploxylon* assemblage

Zones S 1 and S 2 are correlated respectively to zones K 7 and K 8 of Kinki district from the similarity of pollen assemblages and the stratigraphic positions.

C. Hokuriku District

Around Kanazawa City, there distributes the lower Pleistocene Utatsuyama Formation (NIREI, 1970). This Formation overlies unconformably the Omma Formation in which Omma molluscan fauna is contained (KASENO and MATSUURA, 1965).

In the Utatsuyama Formation, marine clay beds of 7 horizons, called UMa 1, UMa 2, ..., UMa 7 in ascending order, are intercalated (NIREI, 1969b).

Plant fossils and paleomagnetic data of the Omma and Utstsuyama Formations are summarized in Fig. 19 (NIREI, 1969a and 1970).

Paleomagnetism:

The paleomagnetic polarity change from reversal to normal in the Utatsuyama Formation is thought to coincide with the Brunhes-Matuyama boundary and that of the Omma Formation is thought to be correlated to the Gauss-Gilbert boundary or earlier (NIREI, 1970). But the correlation of the Omma Formation does not agree with pollen stratigraphy, as will be discussed in the later section.

Pollen data:

From the Omma and Utatsuyama Formations, 10 samples were collected by S. ISHIDA. As the result of pollen analysis by the writer, the following two pollen assemblages are distinguished (Fig. 20).

1) *Picea-Haploxylon* assemblage: A spectrum of the Omma Formation (Ut-1) shows a remarkable high percentage of *Pinus* and *Picea*. This spectrum is thought to belong to the *Picea-Haploxylon* assemblage and it may be concordant to the cold temper-

		OMMA FORMATION	ULG	UMa 1	UMa 2	UMa 3	UMa 4	UMa 5	UMG	UMa 6	UMa 7
Polarity		N N N R		R	N	N	N	N		N	N
Fauna		Omma Molluscan Fauna									
Flora	Tsuga rotundata									+	
	T. oblonga									+	
	Juglans mandshurica			+		+	+				
	J. sieboldiana					+				+	
	Corylus heterophylla			+							
	Fagus microcarpa						+				
	F. crenata	+									
	Quercus crispra	+									
	Q. dentata	+									
	Magnolia kobus	+				+					
	Sapium sebiferum									+	
	Paliurus nipponicus									+	
	Menyanthes trifoliata			+						+	

Fig. 19. Stratigraphy of the Omma and Utatsuyama Formations (after Nirei, 1969a, b and 1970).

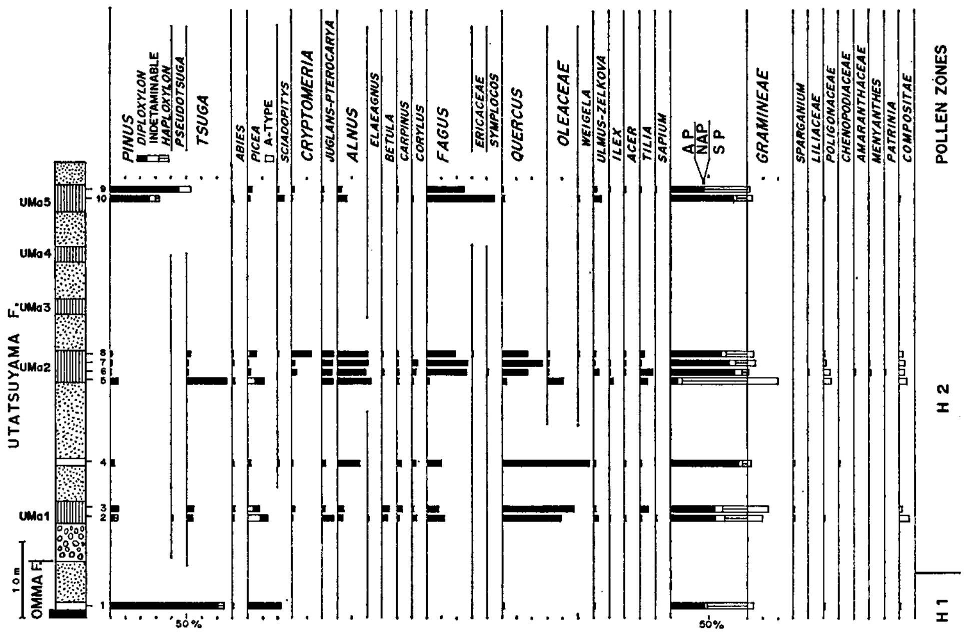

Fig. 20. Pollen diagram of the Omma and Utatsuyama Formations.

ature suggested by the Omma molluscan fauna, consisting of *Patinopecten yessoensis*, *Venericardia nakamurai*, *Antiplanes contraria*, etc.

2) *Fagus-Quercus* assemblage: Almost all samples from the Utatsuyama Formation (Ut-2 to 10) shows a high percentage of *Fagus* and *Quercus*. These may belong to the *Fagus-Quercus* assemblage.

As the Utatsuyama Formation is represented by the *Fagus-Quercus* assemblage, it may be correlated to zone K 6 of Kinki district.

Since there is no occurrence of *Liquidambar* and Taxodiaceae in the Omma Formation, zone H 1 seems to be correlated to K 5 or upper zone of Kinki district.

D. Kanto District

A detailed stratigraphy of the Plio-Pleistocene Kazusa Group in the Boso Peninsula is established by MITSUNASHI and YAZAKI (1958) by tracing pyroclastic markers. Several formations previously named are fixed with the relation to the pyroclastic markers. For the stratigraphy of the overlying Sagami Group, however, there still remain several different opinions. In this paper, the NAKAGAWA's (1960) subdivisions are adopted.

Fauna:

Several proboscidian fossils were reported. Ranges of several representative species are summarized as follows (NARUSE, 1970, ITIHARA *et al.*, 1973, etc.) (Fig. 21).

Stegodon aurorae ranges from the middle Umegase to the lowermost Kokumoto Formations (U_6 to Ku_6).

Elephas proximus is apparently restricted within the Umegase Formation (U_{10} to U_1).

Elephas trogontherii is found from the Kasamori (and Mandano) Formation.

Stegodon orientalis is found from the Kasamori Formation and the Itsukaichi gravels (KANTO LOAM RESEARCH GROUP, 1958). The latter is probably correlated to the Sagami Group.

Elephas naumanni is found from the Yabu Formation and the younger deposits.

The former three species are thought to be very closely related to *Stegodon akashiensis*, *Elephas shigensis* (early type) and *E. shigensis* (later type), respectively.

Paleomagnetism:

The directions of remanent magnetization of silts and silty sands after alternating field demagnetization at peak field of 90 Oe were measured by NAKAGAWA *et al.* (1969). According to them, the Kazusa Group involves 6 polarity epochs, with two normal events in the Matuyama reversed epoch (Fig. 21).

Recently, NIITSUMA (1976) measured the directions of remanent magnetizetion after thermal demagnetization at 200°C in air and alternating field demagnetization at peak field of 180 Oe. He divided the Kazusa and Sagami Groups into BO-A and BO-B magnetozones and BO-B-1 and BO-B-2 magnetosubzones.

A interpretation for the NIITSUMA's polarity records was proposed by ODA (1975).

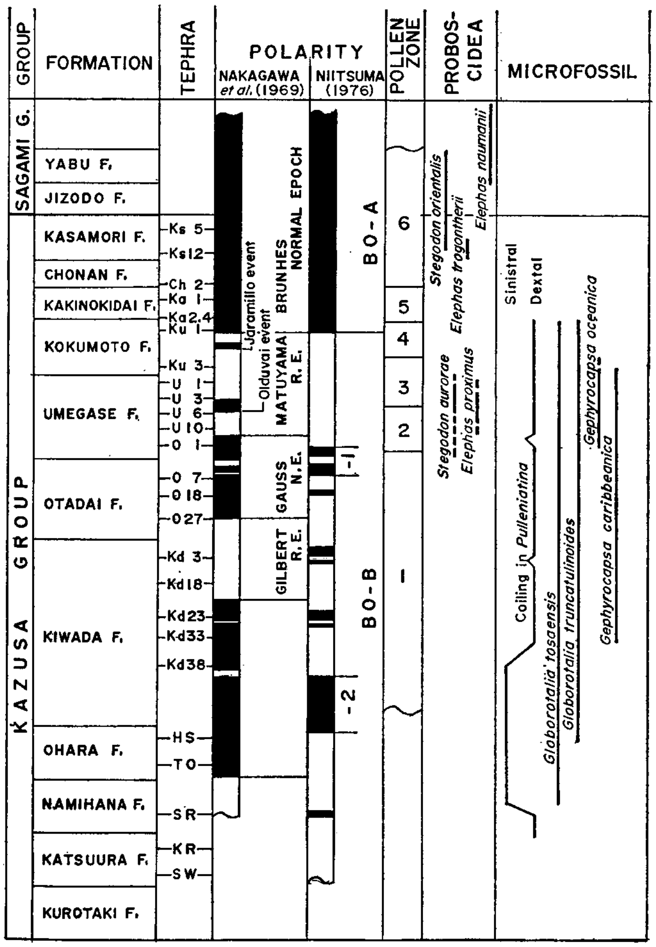

Fig. 21. Stratigraphy in Kanto district (after Itihara *et al.*, 1973, Oda, 1975, etc.).

Based on the range of planktonic foraminifera, he asserts that the major part of the Kazusa Group lower than the middle Kokumoto Formation may correspond to the Matsuyama epoch and that BO-B-1 and -2 magnetosubzones may correspond to the Jaramillo and Olduvai events.

Pollen data:

A pollen diagram of the Kazusa and Sagami Groups was prepared by Sohma in 1961. His work established that a zone rich in *Metasequoia* pollen is in the lower half of Umegase Formation. Another pollen diagram was prepared by the writer (Onishi, 1969b). He established 6 pollen zones, here called zones B 1 to B 6 as shown in Fig. 23. He also presented the correlation with the floral subdivision of the Osaka Group.

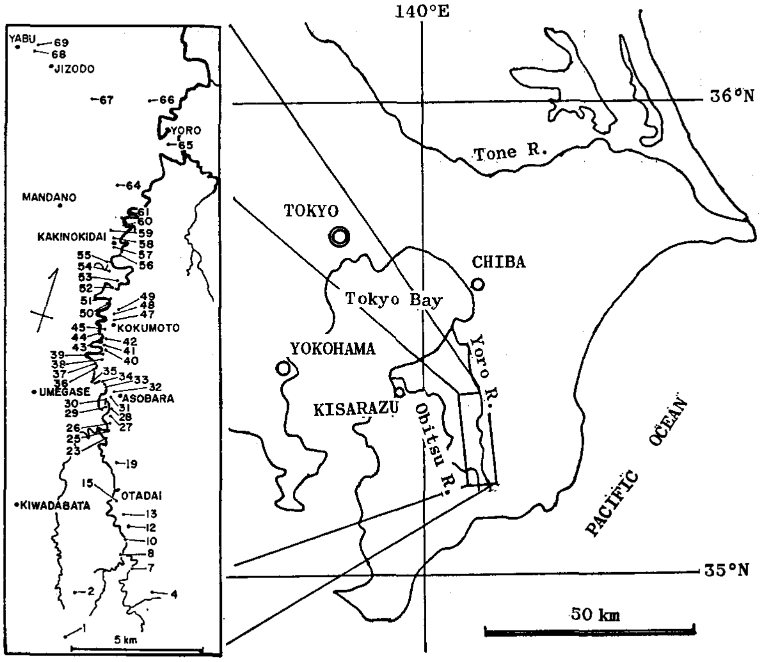

Fig. 22. Locality map of Kanto district (modified from Onishi, 1969b).

Pollen Assemblages

Judging from the pollen spectrum, the following 6 pollen assemblages can be distinguished.

1) Taxodiaceae-Pinaceae assemblage*
2) *Quercus*-Taxodiaceae assemblage
3) *Metasequoia-Picea* A assemblage
4) *Fagus-Quercus* assemblage
5) *Picea-Cryptomeria* assemblage
6) *Picea-Haploxylon* assemblage

The former two assemblages are representatives of zone B 1. The third one is characteristic of zone B 2. The last three repeatedly appear in zones B 3 to B 6.

Correlation with Kinki District

Zone B 1 may be correlative to zones K 1 to K 4 in Kinki and Tokai districts, as there are not a few percent of *Keteleeria* and *Pseudolarix* (?). But the absence of *Carya*, *Nyssa* and *Liquidambar* denies the correlation to zones K 1 to K 3, because these taxa are still rather constantly found in zones K 1 to K 3 as well as in the lower part of the

* This assemblage is characterized by abundant pollen of Taxodiaceae and Pinaceae such as *Pinus*, *Picea* and *Tsuga* (*e.g.* Bos-7 in Fig. 23).

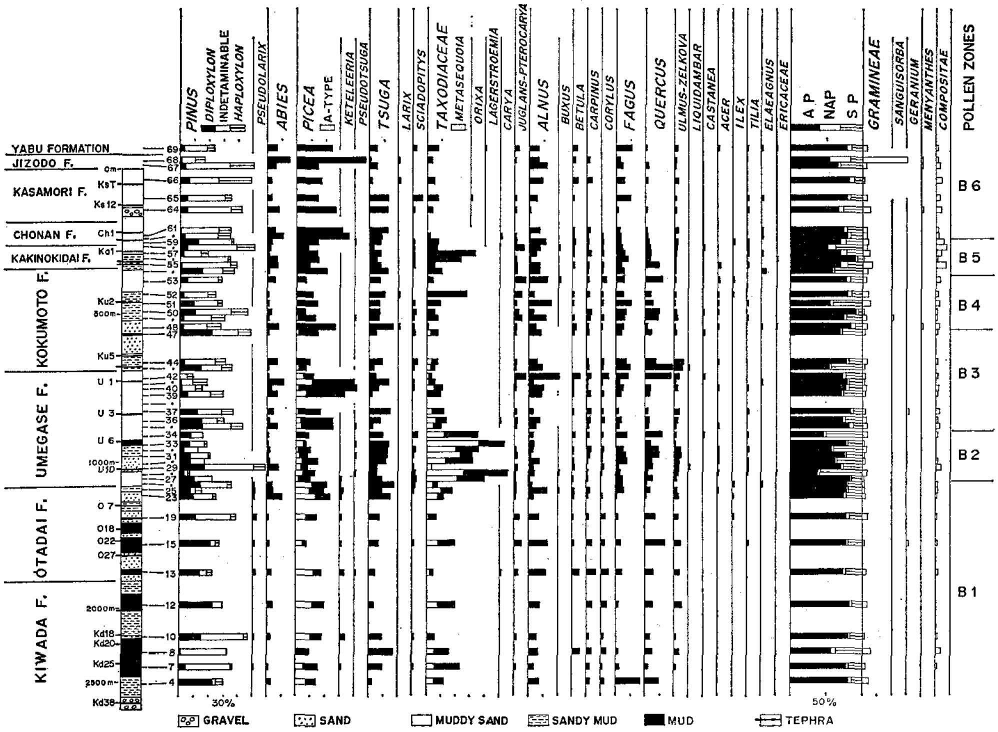

Fig. 23. Pollen diagram in Kanto district (modified from Onishi, 1969b).

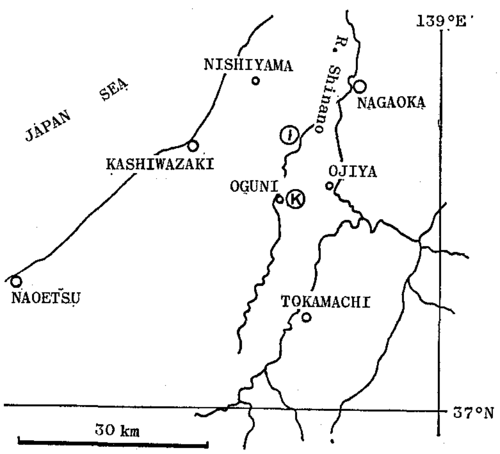

Fig. 24. Locality map of Niigata district. I: Iwata-Yamaya section, K: Kirisawa section.

Chuetsu Group in Niigata district (Shimakura, 1960 and Yamanoi and Nitobe, 1970) which are correlated to zone K 3 and the lower as will be discussed in the following section.

Zones B 2 to B 6 are correlated to the following zones by the similarity of pollen assemblages.

Kanto district		Kinki district
Zone B 2	————	Zone K 5
Zones B 3 and B 4	————	Zone K 6
Zones B 5 and B 6	————	Zone K 7

E. Niigata District

In the Niigata oil field, the Pliocene and Pleistocene strata were surveyed before the World War II and summarized as follows (Makiyama, 1950).

Uonuma Group	Oguni Formation
	Tsukanoyama Formation
Chuetsu Group	Haizume Formation
	Nishiyama Formation
	Shiiya Formation

Since the later half of 1960's, several detailed tephrochronologic studies of the Uonuma Group were begun in Oguni area (Niigata Plain Collaborative Research Group, 1969, 1970 and 1971 and Collaborative Research Group for Niigata Plain, 1973) and Tokamachi area (Yamanoi, 1970, Yamanoi and Nitobe, 1970, Yamanoi *et al.*, 1970 and Suzuki and Yamanoi, 1970). Few years later, both areas were surveyed by Miyashita *et al.* (1970 and 1972). As the result, some key volcanic ash layers of the upper part of the Uonuma Group enabled to make correlation between both areas. But there still remains a disagreement for the lower part. Ranges of some important plant remains, pollen zones, magnetic polarities and fission-track ages of both areas are shown in Fig. 25.

Before these works, Shimakura (1960) analyzed some samples of the Chuetsu Group at Nishiyama oil field. According to him, the Nishiyama Formation contains abundant pollen of *Abies*, *Picea*, *Pinus*, *Tsuga* and Taxodiaceae. *Liquidambar* pollen is stably found in about a half of samples, but *Nyssa* pollen is scarcely found. Pollen spectra from the Haizume Formation show the dominant frequencies of *Abies*, *Picea*, *Fagus* and Taxodiaceae. *Liquidambar* pollen is absent in this horizon except for one sample.

Pollen data:

Pollen diagrams from two sections in Oguni area are presented here.

1) Iwata-Yamaya Section (Fig. 26)

There are three volcanic ash layers in this section. The middle one (T_2) is traced

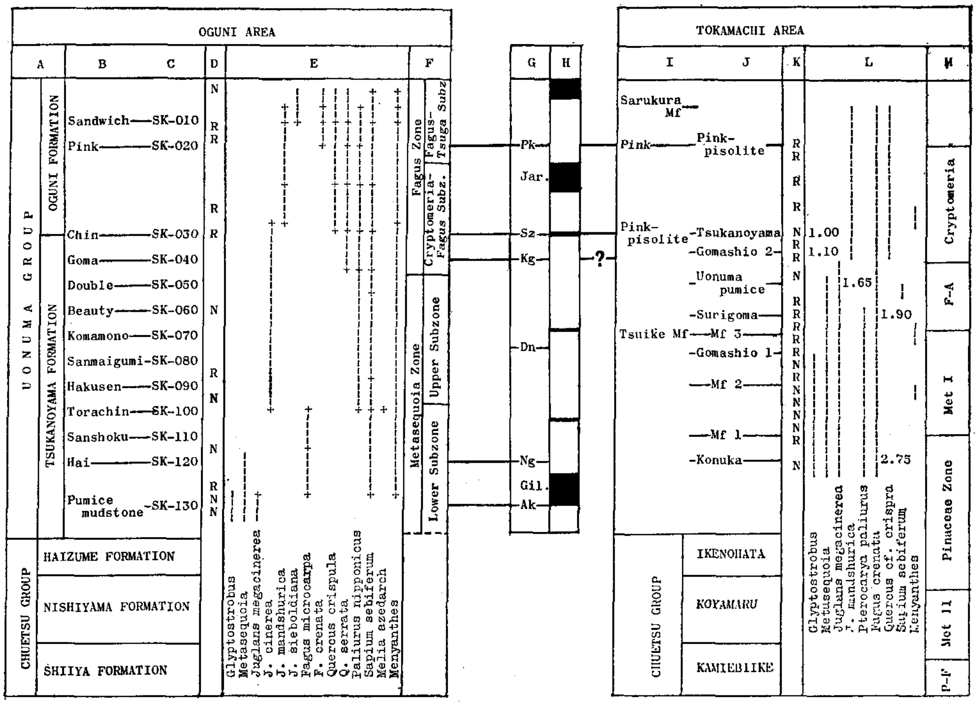

Fig. 25. Stratigraphy in Niigata district.
A: Stratigraphy (after Makiyama, 1950)
B: Volcanic ash layers (Niigata Plain Collaborative Research Group, 1969)
C: Volcanic ash layers (*Ditto*, 1970)
D: Polarity (Collaborative Research Group for Niigata Plain, 1973)
E: Plant fossils (Niigata Plain Collaborative Research Group, 1971)
F: Pollen zones (*Ditto*, 1971)
G: Pyroclastic markers (Miyashita *et al.*, 1970)
H: Polarity by Nitobe and Niizuma (Yamanoi *et al.*, 1970)
I: Key beds (Yamanoi, 1970)
J: Key beds (Yamanoi and Nitobe, 1970)
K: Polarity by Nitobe and Yamanoi (Yamanoi *et al.*, 1970)
L: Plant fossils by Ueno (*Ditto*, 1970) and Fission track ages (million years B.P.) (Suzuki and Yamanoi, 1970)
M: Pollen zones (Yamanoi and Nitobe, 1970), P–F=Pinaceae-*Fagus* zone, Met II=*Metasequoia* II zone, Met I=*Metasequoia* I zone, F–A=*Fagus–Alnus* zone, Cryptomeria=*Cryptomeria* zone

and identified as the Tsukanoyama volcanic ash (SK-030). Therefore, almost all of the samples may belong to the Uonuma Group, but the lower limit is not clear.

The lower two samples (IY-1 and 2) show high pollen frequencies of *Picea*, *Tsuga*, Taxodiaceae and *Fagus*, and they are grouped into the Taxodiaceae-Pinaceae assemblage. There are also found some pollen of *Keteleeria* and *Liquidambar*. These

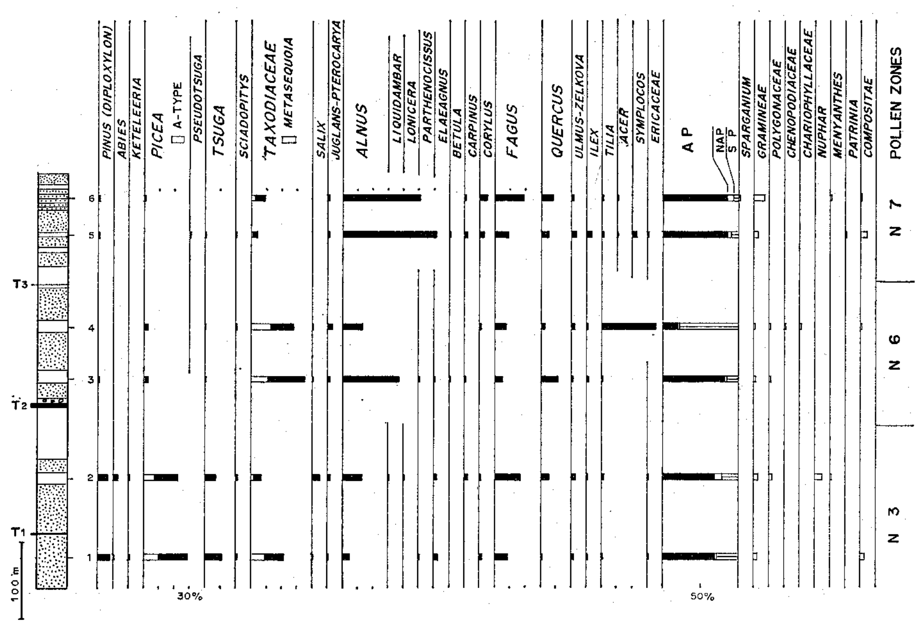

Fig. 26. Pollen diagram at Iwata-Yamaya section.

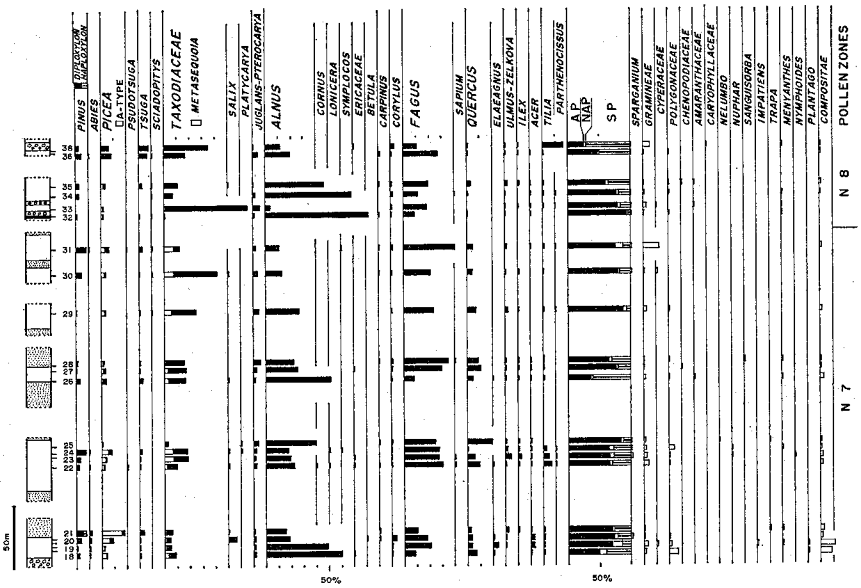

Fig. 27. Pollen diagram at Kirisawa section.

spectra resemble those of the Pinaceae zone of YAMANOI and NITOBE (1970).

The middle two (IY-3 and 4) contain much percentage of Taxodiaceae pollen (*Metasequoia* pollen is comprised). So, they may belong to the *Metasequoia-Picea* A assemblage.

The upper two (IY-5 and 6) contain many pollen of *Alnus*. As there are contained fairly amount of pollen of *Fagus* and *Quercus*, so they may belong to the *Fagus-Quercus* assemblage.

2) Kirisawa Section

The horizons of all samples are above SK-020. Though there is a high percentage of *Alnus*, the pollen percentages of *Fagus*, *Quercus* and *Cryptomeria* are also high. The spectra of Kir-18 to 31 show the features of the *Fagus-Quercus* assemblage and those of Kir-33 to 38 show the features of *Fagus-Cryptomeria* assemblage.

Pollen Zones:

Summarizing the pollen data mentiond above, the following pollen zones are distinguished.

Zone N 8 (Kir-33 to 38 in Fig. 27)

Zone N 7 (Kir-18 to 31 in Fig. 27 and IY-5 and 6 in Fig. 26): corresponds to the *Fagus-Tsuga* Subzone*.

Zone N 6 (IY-3 and 4): corresponds to the *Cryptomeria-Fagus* Subzone* and the *Cryptomeria* Zone**.

Zone N 5: corresponds to the Upper *Metasequoia* Subzone* and *Fagus-Alnus* Zone**.

Zone N 4: corresponds to the Lower *Metasequoia* Subzone* and *Metasequoia* I Zone**.

Zone N 3 (IY-1 and 2): corresponds to the Pinaceae Zone**.

Zone N 2: corresponds to the *Metasequoia* II Zone**.

Zone N 1: corresponds to the Pinaceae-*Fagus* Zone**.

Correlation with Kinki District

As there are contained not so low percentage of *Carya*, *Nyssa* and *Liquidambar* in the Shiiya Formation (YAMANOI and NITOBE, 1970), zone N 1 may be correlative to zone K 2 and lower in Kinki and Tokai districts. Zones N 2 and N 3 may be correlated to zone K 3, as there are also found some pollen grains of *Keteleeria* and *Liquidambar*. From a high percentage of *Metasequoia* pollen, zone N 5 and lower half of zone N 6 may be correlated to zone K 5. Notwithstanding a high frequency of *Cryptomeria*, zone N 8, together with zone N 7 and the upper half of zone N 6, may be correlated to zone K 6.

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* Subzone by COLLABORATIVE RESEARCH GROUP for NIIGATA PLAIN, 1973.

** Zone by YAMANOI, UENO and NITOBE, 1970.

IV. Pollenstratigraphy

A. Climatic estimation from pollen assemblages

1) *Diploxylon-Cryptomeria* assemblage

This assemblage occurs only at the last millennium. It is the result of artificial effects of deforestration, afforestration and cultivation in the warm temperate forest areas.

2) *Cyclobalanopsis-Abies*, *Haploxylon-Cryptomeria* and *Haploxylon-Abies* assemblage

These assemblages compose a set of *Abies* type in San'in district during the last 25,000 years. *Cyclobalanopsis* is one of the most important genus in the warm temperate to subtropic climate zones. Judging from the geographical distribution of living species, *Abies* pollen may be considered to be *A. firma*, of which range is the cool temperate to warm temperate zones. Then, the *Cyclobalanopsis-Abies* assemblage must be restricted within the warm temperate climate.

The cold climate may be represented by the *Haploxylon-Abies* assemblage. This assemblage occurs during the latest Würm glacial age (ONISHI, 1974) and must represent the present subalpine forest in northern Japan.

The *Haploxylon-Cryptomeria* assemblage may occupy the climate between the former two assemblages, *i.e.* the cool temperate climate.

3) *Fagus-Cryptomeria*, *Fagus-Tsuga*, *Picea-Cryptomeria* and *Picea-Haploxylon* assemblages

These assemblages are observed during the late Pleistocene. Excepting the *Fagus-Tsuga* assemblage, these compose a set of *Picea* type in San'in district. During this age, *Picea jezoensis* and *P. maximoviczii* are reported as fossils (ONISHI, 1974). There are two types of the occurrence of these *Picea*, one occurs with *Pinus koraiensis*, *Tsuga diversifolia* and other subalpine forest trees, and the other one with the temperate species as *Chamaecyparis obtusa*, *C. pisifera* and *Buxus japonica*. The *Picea-Haploxylon* assemblage is characteristic of the former flora and the *Picea-Cryptomeria* assemblage is of the latter flora.

The *Fagus-Cryptomeria* assemblage is obtained from the marine clay of the middle terrace and contains a few percent of *Lagerstroemia* and *Buxus* pollen. *Lagerstroemia* is now living in southern Kyushu. As there is no occurrence of warmer assemblage, the *Fagus-Cryptomeria* assemblage seems to represent the warm temperate forest at that time.

The *Fagus-Tsuga* assemblage also contains *Lagerstroemia* pollen, so it may occupy the similar habitat to that of the *Fagus-Cryptomeria* assemblage.

4) *Cyclobalanopsis-Poducarpus* assemblage

This assemblage occurs only in Ma 8 of the Osaka Group, where the subtropic *Syzygium* flora is reported (MIKI *et al.*, 1957). This assemblage suggests the subtropic climate.

5) *Fagus-Quercus* and *Ulmus-Zelkova* assemblages

The *Fagus-Quercus* assemblage occurs in the marine clay beds, while the *Fagus-Cryptomeria* assemblage is obtained only from fresh-water clays in the lower half of the upper part of the Osaka Group. So the climatic condition of the former may be somewhat warmer than the latter. Then, the *Fagus-Quercus* assemblage indicates the warm temperate climate.

The *Ulmus-Zelkova* assemblage is observed only in the Oita Group. Judging from the southern situation of Oita district, this assemblage seems to indicate somewhat warmer condition than the *Fagus-Quercus* assemblage.

6) The other assemblages

In the horizons older than the upper part of the Osaka Group, the exotic and extinct taxa occupy the majority, so the climatic estimation is more difficult.

The *Cyclobalanopsis-Carya* assemblage may occupy warmest climate. The *Quercus-Liquidambar*, *Quercus*-Taxodiaceae, and Taxodiaceae-*Zelkova* assemblages may occupy the warmer position. The *Metasequoia-Picea* A and *Fagus-Nyssa* assemblages may indicate a rather cool climate. The Taxodiaceae-Pinaceae assemblage seems to occupy a somewhat cold climate zone.

B. Pollen zones

Pollen zones obtained from 6 districts stated in the foregoing chapters can be summarized as follows (Fig. 28).

1) *Abies* Zone

It is represented by zone S 2 of San'in district. The base of this Zone is estimated at about 25,000 years B.P. in age from the radiocarbon dating (ONISHI, 1974). So this Zone ranges from the latest Pleistocene to Holocene.

2) *Cryptomeria* Zone

It is represented by zone K 7 of Kinki district. This Zone ranges from Ma 6 of the Osaka Group (about 0.5 million years B.P.) to the low terrace deposits in Kinki district.

3) *Fagus* Zone

It is represented by zone K 6 of Kinki district. This Zone ranges from approximately Ma 1 to Ma 5 of the Osaka Group.

4) *Metasequoia* Zone

It is represented by zone K 5. This Zone includes Ma 0 of the Osaka Group. The Plio-Pleistocene boundary was estimated by ITIHARA (1960) near the base of this Zone*.

5) Taxodiaceae Zone

It is represented by zone K 4. This Zone occupies the upper half of the lowermost part of the Osaka Group.

* The problems of the Plio-Pleistocene boundary in Japan was fully discussed by ITIHARA *et al.* (1973).

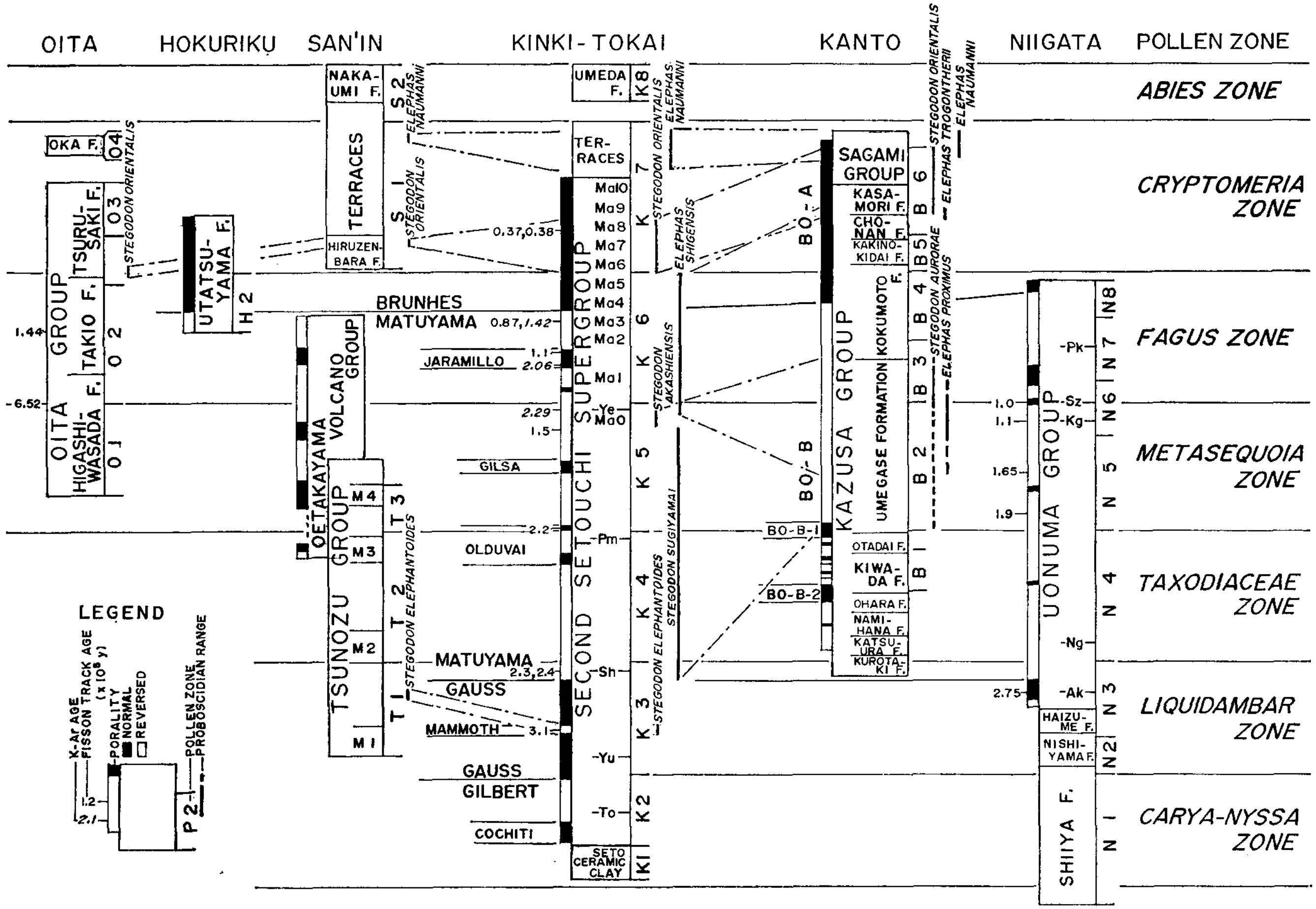

Fig. 28. Correlation of Pollen Zones and the other criteria.

6) *Liquidambar* Zone

It is represented by zone K 3. This Zone occupies the lower half of the lowermost part of the Osaka Group.

7) *Carya-Nyssa* Zone

It is represented by zones K 1 and K 2 of Kinki and Tokai districts. This Zone occupies the lowest part of the second Setouchi Supergroup.

C. Relations to the correlations based on the other methods

a) Proboscidean Fauna

Some proboscidean species are reported from more than two districts. These species give another means of correlation.

Elephas naumanni is found from San'in, Kinki and Kanto districts. The range of this species is restricted within the upper half of the *Cryptomeria* Zone.

Stegodon orientalis is reported from Oita, San'in, Kinki and Kanto districts. The range of this species is limited in the lower half of the *Cryptomeria* Zone.

Stegodon aurorae and *Elephas proximus* are reported from the Umegase Formation in Kanto district. These species are thought to closely relate to *Stegodon akashiensis* and *Elephas shigensis* (early type) from Kinki district (ITIHARA *et al.*, 1973). The coexistence of the latter two species is limited near Ma 0 of the Osaka Group.

Stegodon elephantoides is found from the horizon in the *Liquidambar* Zone of the Tsunozu and Agé Groups.

Generally speaking, the correlation by pollen zones well agrees with the proboscidean correlation (Fig. 28).

b) Paleomagnetism

Paleomagnetic chronology is proposed in almost all districts.

The boundary between the Brunhes and Matuyama epochs is restricted within the upper part of the *Fagus* Zone in Hokuriku, Kinki, Kanto and Niigata districts.

The Jaramillo event is reported from Kinki and Niigata districts at the horizon within the *Fagus* Zone. BO-B-1 magnetosubzone in Kanto district which was correlated to this event (ODA, 1975) is, however, located at the boundary between the *Metasequoia* and Taxodiaceae Zones.

The Gilsa event is reported from Kinki district within the *Metasequoia* Zone. In Niigata district, this event is estimated within the *Liquidambar* Zone. The fission-track age in the horizon of this normal event was measured as 2.75 million years B.P. (SUZUKI and YAMANOI, 1970). This figure suggests that this horizon is correlated to the Gauss epoch.

The Olduvai event is situated approximately at the top of the Taxodiaceae Zone in Kinki district. In Kanto district, BO-B-2 magnetosubzone which was correlated to this event (ODA, 1975) is located within the Taxodiaceae Zone.

The Matuyama-Gauss boundary is reported from Kinki district at the upper part of the *Liquidambar* Zone. In Niigata district, this boundary is estimated within the upper half of the *Liquidambar* Zone. In Kanto district, this boundary may be located below the Taxodiaceae Zone.

The Gauss-Gilbert boundary is situated at the upper part of the *Carya-Nyssa* Zone in Kinki and Tokai districts.

c) Absolute Ages

The base of the *Abies* Zone was estimated at about 25,000 years B.P. from the radiocarbon dating (Onishi, 1974). This figure is not contrary to the data from Kinki district.

Fission-track and K-Ar ages were measured in Kinki, Niigata and Oita districts. Fission-track ages from Kinki and Niigata districts are well consistent with each other. But the figures of fission-track age from Oita district, as well as those of K-Ar age from Kinki district, do not agree with the pollen and paleomagnetic data.

Fission-track ages from Kinki and Niigata districts give the following figures to the bases of some pollen zones.

The base of *Cryptomeria* Zone	about 0.5 million years
The base of *Fagus* Zone	about 1.0 million years
The base of *Metasequoia* Zone	about 2.0 million years

Generally speaking, the correlation by means of pollen zones well agrees with that made by other methods, though some disagreements still remain.

V. Summary

1. The Pliocene and Pleistocene pollen assemblages from six districts in central and southwest Japan are carefully examined. Pollen spectra are summarized into 18 pollen assemblages. The stratigraphic distribution of each pollen assemblage is determined in each district. The climatic condition of each assemblage is estimated mainly from the representative pollen taxa.

2. The most complete sequence is obtained from Kinki and Tokai districts. In total, 8 pollen zones are distinguished in these districts since the Pliocene and are used as the standard for correlation.

3. The Pliocene and Pleistocene strata from the other five districts are subdivided into 2 to 8 pollen zones, which can be correlated to the standard zones.

4. Pollen zones from all districts are summarized into seven Pollen Zones, named as the *Abies*, *Cryptomeria*, *Fagus*, *Metasequoia*, Taxodiaceae, *Liquidambar*, and *Carya-Nyssa* Zones in descending order.

5. The Plio-Pleistocene boundary in Kinki district approximately agrees with the lower boundary of the *Metasequoia* Zone.

6. When comparing the various correlations based on the proboscidean fossils, the paleomagnetic chronology, the fission-track ages and the pollen zones, these correlations well agree with each other.

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Appendix

RANGE CHART OF PLANT FOSSILS IN KINKI AND TOKAI DISTRICTS

Compiled from the following papers.

FUKAKUSA RESEARCH GROUP, 1962, HIKITA, 1954, HUZITA, 1954, IBARAGI RESEARCH GROUP, 1966, ISHIDA *et al.*, 1969, ITIHARA, 1960 and 1961, ——— *et al.*, 1955 and 1966, ITOIGAWA, 1971, KOKAWA, 1955, 1961, 1962a, 1962b and 1963, KOMYOIKE RESEARCH GROUP, 1971, MIKI, 1933, 1937, 1938, 1941a, 1941b, 1948, 1950, 1952, 1953, 1955a, 1955b, 1956a, 1956b, 1956c, 1957, 1958, 1960, 1961, 1963, 1965, 1968 and 1969, ——— *et al.*, 1957 and 1962, NIREI, 1968, NISHIYAMA RESEARCH GROUP, 1967, ——— *et al.*, 1970, TAKAYA, 1963, ——— and ITIHARA, 1961, YOSHINO, 1971, etc.

Markings:

+: The horizon is clear
–: The horizon is not clear but estimated from the assosiated species
s: Species is not determined
c: Species is compared
?: Species is uncertain
*: Exotic or extinct species

SPECIES \ DIVISION	1	2	3	4	5	6	7	8	9	10	H	M	L	A
Dicranopteris dichotoma (Thunb.) Bernh.									+					
Osmunda japonica Thunb.	+					–	–							
Pteridium aquilinum (L.) Kuhn							–	–	–					
* *Ginkgo biloba* L.					+									
Taxus cuspidata S. et Z.							–							+
Torreya nucifera (L.) S. et Z.					+		+	–	+					+
Podocarpus macrophyllus (Thunb.) Lamb.														+
nagi (Thunb.) Zoll. et Moritzi									+					

Species \ Division	1	2	3	4	5	6	7	8	9	10	H	M	L	A
* *Cephalotaxus biumbonata* Miki	+													
drupacea S. et Z.							+	−			+	+		+
* *obovata* Miki				+	+		+	−	+					
Abies firma S. et Z.	s			−	+	+	+	+	+		+	+	+	+
homolepis S. et Z.							+		+				+	
veitchii Lindl.									+				+	
* *Keteleeria davidiana* (Franch.) Beissn.	+			−	+									
* *robusta* Miki	+													
* *Larix gmelini* Gordon									+					
kaempferi (Lamb.) Sarg.													+	
Picea bicolor (Maxim.) Mayer				−	−	+	−	−	+				+	+
jezoensis (S. et Z.) Carr.									+				+	
* *koribai* Miki	+			+	+	+	−							
koyamai Shirasawa							+						+	
* *latibracteata* Miki	+		+											
maximowiczii Regel				+	+	+	+	−	+	+		c	+	
polita (S. et Z.) Carr.				+		+	−						+	
Pinus (*Diploxylon*) *densiflora* S. et Z.						+	+	+	+	−		+	+	
* *fujiii* Miki	+		+	−	+									
* *oligolepis* Miki				+		+	+		+					
thunbergii Parl.						+	+	+	+	−	+	+	+	+
* *trifolia* Miki	+													
* (*Haploxylon*) *armandii* Franch.	+			+										
koraiensis S. et Z.						+		−	+	+		+	+	
parviflora S. et Z.						+	+	−					+	
* *Pseudolarix kaempferi* Gord.	+	+	+	+	+									
* *Pseudotsuga gondylocarpa* Miki						+			+					
japonica (Shirasawa) Beissn.				−	+	+	+		+			+	+	+
* *subrotunda* Miki	+		+	+	+	+	+				+			
Tsuga diversifolia (Maxim.) Mast.													+	
* *longibracteata* Cheng	+				−	+	+							
* *oblonga* Miki	+						−	+	−	+				
* *rotundata* Miki				+	+	+	+							
sieboldii Carr.								−	+			+	+	+
Cryptomeria japonica (L. f.) D. Don				+	−	+	+	+	+	+	+	+	+	
* *Cunninghamia konishii* Hayata	+	+		−	+	+	+							
* *Glyptostrobus pensilis* Koch.	+	+	+	+	+	−								
* *Metasequoia disticha* (Heer) Miki		+	+	+	+	+	+							
* *japonica* Miki	+		+		+	−								
* *Protosequoia primarium* (Miki) Miki	+													
* *Sequoia couttisie* Heer	+	+	+	+	+	−								
* *Taiwania cryptomerioides* Hayata					+									
Sciadopitys verticillata (Thunb.) S. et Z.		+					+	+	+		+		+	+
Chamaecyparis obtusa (S. et Z.) S. et Z.						+	+	+	+		+		+	+
pisifera (S. et Z.) S. et Z.				−	+	+	+	+	+		+	+	+	+
Juniperus chinensis L.				+		−							+	
conferta Parl.							+	+				+		
rigida S. et Z.									+					+

SPECIES \ DIVISION	1	2	3	4	5	6	7	8	9	10	H	M	L	A
* *Thuja koraiensis* Nakai				−	+	+	+	−	+					
standishii (Gordon) Carr.								−	+				+	+
Thujopsis dolabrata (L. f.) S. et Z.				−	+		−	−	+					
Salix sp.	+			−	−	+	−	+						+
Myrica gale L.													+	
rubra S. et Z.									+					+
Alnus hirsuta Turc. var. *sibirica* Sch.									+				+	+
japonica (Thunb.) Steud.	+		+	−	+	+	+	+	+	+	+	+	+	
matsumurae Call.													+	+
* *Betula adstigmata* Miki	+													
ermanii Cham.													+	
grossa S. et Z.													+	
platyphylla Sukat.									+					
Carpinus carpinoides Makino	+													
erosa Blume						+							+	
laxiflora (S. et Z.) Blume						+	−	+						
tschonoskii Maxim.								+						+
Corylus heterophylla Firch.			+	+	+	+	−	−	+			+	+	
* *ligniatus* Miki	+													
Ostrya japonica Sarg.						+							+	
* *stenocarpa* Miki	+													
Castanea crenata S. et Z.												+		
Castanopsis cuspidata (Thunb.) Schottky														+
* *oligospina* Miki	+													
Cyclobalanopsis gilva (Blume) Oerst.								−	+					+
glauca (Thunb.) Oerst.									+					+
myrsinaefolia (Blume) Oerst.														+
paucidentata (Fr.) Kudo et Masamune									+					
salicina (Blume) Oerst.														+
Fagus crenata Blume				−	−	+	+	−	+				+	
* *ferruginea* Ait.	+				+									
* *hayatae* Palib.				+	+	+	+	+	+					
japonica Maxim.		+		−	+		+				+		+	+
* *japonicoides* Miki	+													
* *microcarpa* Miki					+		−	+		+	+			
Lithocarpus glabra (Thunb.) Nakai	+													
Quercus aliena Blume						−	−		+					+
acutissima Carr.		+		−	−	−	−	−						
* *chenii* Nakai	+													
crispula Blume							+					+	+	
* *hikitai* Miki					+									
phillyraeoides A. Gray									+					
* *rubroidea* Miki	+	+	−	+	+	+	+	−	−					
serrata Thunb.					+		+	−	+		+	+	+	+
variabilis Blume						+	−							
* *Carya ovatocarpa* Miki	+													
* *striata* Miki	+		+											
* *venticosa* Unger	+													

SPECIES \ DIVISION	1	2	3	4	5	6	7	8	9	10	H	M	L	A
* *Juglans mandshurica* Maxim.						+	+	+						
* *megacinerea* Chaney	+	+	+	+	+	+								
sieboldiana Maxim.							+	+	+	+	+	+		+
* *Pterocarya paliurus* Batal.	+		+	+	+	+	−							
rhoifolia S. et Z.													+	+
* *stenoptera* DC.				+		+	+							
Aphananthe aspera (Thunb.) Planch.														+
Celtis sinensis Pers.							−							+
* *Hemiptelea davidiana* Planch.								+	+			+		
Ulmus parvifolia Jacq.						+	−							
* *Zelkova ungeri* Kovats.	c	+		−	+	+	+	+	+		s			
* *Eucommia ulmoides* Oliv.	+													
Ficus pumila L.						+								
Morus sp.						+								
Polygonum maackianum Regel.						+	−							+
thunbergii S. et Z.														+
Ceratophyllum demersum L.				−	+	+	+	+	+		+	+	+	+
Brasenia schreberi Gmel.	+	+	+	−	−						+			+
* *Eoeuryale brasenioides* Miki	+													
* *Euryale europaea* Weber								−						
ferox Salisb.						−	+	−	+			+		+
* *lissa* Reid.		+	+	+	−	−								
* *nodulosa* Reid.				−	−	+								
* *Nelumbo nucifera* Gaertn.						−	+	+	+				+	+
* *Nuphar akashiensis* Miki	+	+	+	+	−	+	−		+					
japonicum DC.							−	−	+			+		+
Nymphaea tetragona Georgi									+			+		+
Cocculus trilobus (Thunb.) DC.			+				−	+				+		+
Sinomenium acutum (Thunb.) Rehd. et Wils.	+													+
Stephania japonica (Thunb.) Miers			+					−				+		
* *periporosa* Miki	+													
Cericidiphyllum japonicum S. et Z.								−	−			+	+	
* *Berberis longispinus* Miki						+	+	−	+					
thunbergii DC.							−							
Cinnamomum camphora (L.) Sieb.														+
daphnoides S. et Z.									+					
doederleinii Engl.									+					
Lindera citriodora (S. et Z.) Hemsl.	+													
umbellata Thunb.	+							+			+			
Machilus japonica S. et Z.	s													+
Neolitsea aciculata Koidz.								−	+				+	
Parabenzoin praecox (S. et Z.) Nakai								−	+					
Magnolia kobus DC.					+	+	+	−	+			+		+
obovata Thunb.				+	+	+	+	−	+		+			+
salicifolia (S. et Z.) Maxim.	+								+		+			
stellata Maxim.			+											
Michelia compressa (Maxim.) Sarg.	s								+					
Illicium religiosum S. et Z.								+	+			+		+

Species \ Division	1	2	3	4	5	6	7	8	9	10	H	M	L	A
Schisandra chinensis (Turcz.) Baill.													+	
* *megasperma* Miki	+				+			c						
nigra Maxim.								−						
* *phytolacoidea* Miki						−	+	−	+					
Evodia sp.						−								
Fagara ailanthoides (S. et Z.) Engl.	+			−	−	+		+				+		
schinifolia (S. et Z.) Engl.							−		+					
Phellodendron amurense Rupr.				+	+	+	+	−	−			+	+	+
Zanthoxylum piperitum DC.						+	−		+			+		+
Melia azedarach L.	c			+	−	+	+	−	+		+	+		
* *Ailanthus altissima* Swingle								+						
Aleurites cordata (Thunb.) Brown ex St.						+	−	−	+			+		
* *fordioides* Miki	+													
Mallotus japonicus (Thunb.) Muell-Arg.									+					+
* *protojaponicus* Miki	+				+									
Sapium japonicum (S. et Z.) Pax. et Hoff.						?		+	+					
* *sebiferum* (L.) Roxb.	+				+	+	+	+	−			+		
Buxus japonicus Muell-Arg.	+	+	+	+	+	+	+	−	+		+	+	+	
Rhus toxicodendron L.							−							
Poupartia axillaris (Roxb.) King et Pr.			+		+									
* *polymeris* (Miki) Miki	+													
* *Ilex cornuta* Lindl. et Paxt.				+	+	+	+	−	+					
macropoda Miq.								−						
pedunculosa Miq.								+						
rotunda Thunb.														+
Hosiea japonica (Makino) Makino							−	−						
Euscaphis japonica (Thunb.) Kanitz.	+		+	−	+		−	+	+					
Staphylea bumalda DC.				+	+	+	−	−	+			+		+
* *Acer buergerianum* Miq.	+													
crataegifolium S. et Z.							+	−						
diabolicum Blume ex Koch	+					+		−	+			+		
ginnala Maxim.								−						
japonicum Thunb.													+	
miyabei Maxim.						c		c	+				+	
nikoense Maxim.							−	−						
* *nordenskioldi* Nath.					+	+								
palmatum Thunb.	+													+
rufinerve S. et Z.						+	−						+	
* *rubrum* L. var. *ligniatum* Miki	+			+										
Aesculus turbinata Blume						+	+	−	+			+		+
Sapindus mukorossi Gaertn.								+				+		+
Meliosma myriantha S. et Z.									+					
* *radiocosta* Miki	+				+									
rigida S. et Z.						−								+
Sabia japonica Maxim.	+		+		+		−	−	+		+			
Berchemia racemosa S. et Z.	+		+	−	+	+	+	+	+			+		+
* *Paliurus nipponicus* Miki	+		+	+	+	+	+	+	+			+		
ramosissimus (Lour.) Poir.														+

SPECIES \ DIVISION	1	2	3	4	5	6	7	8	9	10	H	M	L	A
Rhamnella franguloides (Maxim.) Weberb.							–	–						
Rhamnus crenata S. et Z.								–						+
Sageretia theezans (L.) Brongn.					+	–	–							
Ampelopsis brevipedunculata (Maxim.) Tr.			+	+		+	–	+				+		+
leeoides (Maxim.) Planch.								–						+
Cayratia japonica (Thunb.) Gagn.												+		
* *megasperma* (Miki) Miki	+							–						
* *orbitalis* Miki	+				+									
Parthnocissus tricuspidata (S. et Z.) Pl.						+								
* *Tetrastigma japonica* Miki								–						
* *tazimiensis* Miki	+													
* *Vitis brachypoda* Miki	+													
coignetiae Pulliat.								–				+	+	+
flexuosa Thunb.					+									
* *labruscoidea* Miki	+							–						
* *rotundata* Miki	+	+		+	+	+	–	+						
thunbergii S. et Z.			+	c	+	c	c	+	c			c		+
Elaeocarpus decipiens Hemsl.											?			
* *Tilia costata* Miki	+					s								
* *Reevesia thyrosoidea* Lindl.					+									
Actinidia polygama (S. et Z.) Maxim.													+	
* *Camellia angulata* Miki	+													
japonica L.						+		–						+
sasanqua Thunb.	+								+					
Cleyera ochnacea DC.						–	–		+					+
Eurya emarginata Makino					+	–	–					+		
Stewartia monadelpha S. et Z.				–	+	+	–							
* *obovata* Miki	+													
pseudocamellia Maxim.				+	+	+	–							
* *Schima plioceca* Miki	+													
Ternstroemia japonica Thunb.								–						
Andromeda polifolia L.													+	
Enkianthus campanulatus (Miq.) Nicolson	s												+	
Oxycoccus palustris Pers.									+				+	
Pieris japonica (Thunb.) D. Don	+	+	+	–	+		–	+						
* *Rhododendron ovatocarpa* Miki	+													
* *Meliodendron multistriatum* (Miki) Miki	+		+											
* *nipponicum* Miki	+		+											
Pterostyrax corymbosa S. et Z.			+	+	–									+
* *Rehderodendron elliptica* Miki	+								+					
Styrax japonica S. et Z.		+	+		+	+	+	+	+	+	+	+		+
* *laevigata* Miki	+													
* *microcarpa* Miki					+	+	+							
obassia S. et Z.						+	–	–				+	+	+
* *obassioidea* Miki	+		+			–								
* *rugosa* Miki	+	+	+											
shiraiana Makino					+	+	+		+					
Symplocos crataegoides Buch-Horm.						+	–							+

Species \ Division	1	2	3	4	5	6	7	8	9	10	H	M	L	A
glauca (Thunb.) Koidz.														+
lancifolia S. et Z.	+													
lucida S. et Z.									+					
myrtacea S. et Z.	+				+									
prunifolia S. et Z.						+			+					+
* *reticulata* Miki							–	–	+					
theophrastaefolia S. et Z.								–						+
* *tricarpa* Miki	+				+									
Menyanthes trifoliata L.						+	+	–	+			+	+	
* *Nymphoides oblonga* Miki		–												
peltata O. Kuntze						–	–	–						
Chionanthus sp.						+		–					+	
Fraxinus japonica Blume	+													
longicuspis S. et Z.									+					
Osmanthus ilicifolius (Hassk.) Mouill.							–	+	+			+		
Syringa sp.	+													
Ehretia dicksonii Hance								–				+		
thyrsiflora (S. et Z.) Nakai								–						
Callicarpa mollis S. et Z.														+
Clerodendron trichotomum Thunb.						–	–	–	+					
Premna japonica Miq.								–						
Vitex rotundifolia L. f.						–	–	–				+		+
* *Eotrapa tetrasepala* Miki	+													
* *Trapella lissa* Miki	+					+		–						
* *primaria* Miki	+													
sinensis Oliver				–	–			–						+
Schoefia sp.								–				+		
Viscum coloratum Nakai				–	+	+	–	+	–					+
Hydrangea petiolaris S. et Z.	+													
Pittosporum tobira (Thunb.) Ait.								–						
Corylopsis sp.	+							–					+	
Disanthus cercidifolius Maxim.													+	
Distylium racemosum S. et Z.									+					
* *Distylopsis parrotioides* Miki	+		+	–	+	–	+	+						
* *Eodistylium* sp.									+					
* *Fortunearia sinensis* Rehd. et Wils.	+	+	+		+									
Hamamelis japonica S. et Z.					+	+	–	–					+	
* *Liquidambar formosana* Hance	c	+	+	+	+									
Chaenomeles japonica Lindl.						+								
Comarum palustre L.													+	
* *Crataegus* sp.								–						
Pourthiaea villosa (Thunb.) Decne.							–							
Prunus donarium Sieb.							–	–	+					
maximowiczii Rupr.							–		+				+	
* *salicina* Lindl.				+		+	c	–	+		c		+	
serrulata Lindl.						+			+					+
Pyrus sp.					+									
* *Rosa akashiensis* Miki						+	–	+	+					

Species \ Division	1	2	3	4	5	6	7	8	9	10	H	M	L	A
multiflora Thunb.						+	−							+
Rubus sp.												?	+	+
Gleditsia japonica Miq.					+	+	+	−						
* *macrocantha* Desf.	c				+	c								
Lespedeza sp.					+									
Wisteria brachybotrys S. et Z.				+		+	+	+	−					
floribunda (Willd.) DC.					+	−	−		−					+
* *ligniata* Miki	+					−	−							
* *Hemitrapa trapelloidea* Miki	+				+									
* *Trapa antheformata* Miki		+		−	−	−	+				+			
* *deformata* Miki				−	−	?								
* *discoidopoda* Miki						−	−	+						
* *dolichocarpa* Miki		+												
incisa S. et Z.			+	−	+	+								+
macropoda Miki			+	−	−	+	+	+	+		+			
* *mammillifera* Miki		+	+	−	+	+	+	+	+		+			
* *manshurica* Flerow						−	−							+
* *maximowiczii* Korsh.	+		+	−	−	+	−	−	+		+			
* *octotuberculata* Miki				−	+									
* *platycerata* Miki				+		−	+	−			+			
* *pulvinipoda* Miki	+													
* *tetragona* Miki								+	+					
* *Lagerstroemia indica* L.	s			−	−	+	+	−	−			+		
Syzygium buxifolium Hook. et Arn.									+			?		
Daphne kiusiana Miq.							c							
* *Elaeagnus akashiensis* Miki	s				s	+	−	+	−			+		
* *Nyssa pachycarpa* Miki	+	+	+	+										
* *rugosa* Miki	+	+	+											
* *sylvatica* Marsh	+		+	+	+									
* *Alangium begonifolium* (Roxb.) Baill.	+				+		−							
* *macrocarpum* Miki	+						+							
Benthamia japonica S. et Z.	+					−	−						+	
Cornus brachypoda C. A. Mayer							−	−			+			+
controversa Hemsley	+		+		+	+	−	−	−	+	+	+	+	+
* *microcarpa* Miki						−	−							
Acanthopanax sieboldianus Makino							c	c						
Aralia elata (Miq.) Seemann						+		+						+
Oenanthe stolonifera DC.								−	+					+
Uncaria rhynchophylla Miq.														+
Sambucus sieboldiana (Miq.) Schwer.						+								
Viburnum dilatatum Thunb.							−							
furcatum Blume								−	+				+	
japonicum (Thunb.) Sprengel	+													
opulus L.													+	
tomentosum Thunb.				+	+		−							
Actinostemma lobatum (Maxim.) Maxim.						−	−						+	+
* *Lissopepon melothroidea* Miki	+													
Trichosanthes kirilowii Maxim.	+													

Species \ Division	1	2	3	4	5	6	7	8	9	10	H	M	L	A
Sparganium glomeratum Laestadius									+				+	
japonicum Rothert							−	+	+		+			
* *protojaponicum* Miki		+	+			−								
ramosum Hudson							−							+
stenophyllum Maxim.													+	
Potamogeton cristatus Regel et Maack						+	−	+					+	
distinctus Benn.						−	−	−	+					+
fryeri Benn.			+						+					
gramineus L.													+	
maackianus Benn.							−	+						
malaianus Miq.								+						
oxyphyllus Miq.							−	+			+			+
pectinatus L.							−	+	+					
perfoliatus L.								−	−		+		+	
pusillus L.								+					+	
Ruppia maritima L.							−	−	+			+		
Zostera nana Roth									+					
Najas major All.								+			?			+
Alisma canaliculatum A. Br. et Bouché							−	−						
Caldesia reniformis (Don) Makino							−	−			+			
* *tertiaria* Dorof.								−	+					
* *Sagittaria centrostyla* Miki							−							
* *Bambusoidea nipponica* Miki	+													
Leersia oryzoides (L.) Swartz													+	
Miscanthus sacchariforus (Maxim.) Bent.									+					+
Molinia japonica Hackel						+							+	
Phragmites communis Trinius						−	−	−	−				+	+
Phyllostachys sp.									+					
Pleioblastus variegata Makino				+										
Sasa sp.						+								
Carex michauxiana Böeckeler								+	+				+	
vesicaria L.							−	+	+					
* *Fuirena tokyoensis* Miki									+					
Scirpus maritimus L.						−	−							+
mucronatus L.						−	−	−	−		+	+	+	+
Aneilema keisak Hassk.								−				?	+	
Iris ensata Thunb.						−	−		−			+	+	
laevigata Fisch.													+	+